| OCRWM | DESIGN CALCULATION OR ANALYSIS COVER SHEET | 1. QA: QA |
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**5. Title**

Dry Transfer Facility Criticality Safety Calculations

**6. Group**

Licensing & Nuclear Safety/Criticality

**7. Document Status Designation**

☒ Preliminary      ☐ Final      ☐ Cancelled

**8. Notes/Comments**

An LP-2.14Q-BSC review was completed on May 16, 2005. During the review, the document title was changed from Surface Facility Criticality Safety Calculations to Dry Transfer Facility Criticality Safety Calculations.

| Attachments | Total Number of Pages |
| --- | --- |
| Attachment I: List of Computer Files | 5 |
| Attachment II: One Compact Disc | N/A |
| Attachment III: General Arrangement Drawings of the Dry Transfer Facility and its Remediation Area | 26 |
| Attachment IV: Sketch of DTF Staging Tube Layouts | 1 |

**RECORD OF REVISIONS**

| 9. No. | 10. Reason For Revision | 11. Total # of Pgs. | 12. Last Pg. # | 13. Originator (Print/Sign/Date) | 14. Checker (Print/Sign/Date) | 15. QER (Print/Sign/Date) | 16. Approved/Accepted (Print/Sign) | 17. Date |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 00A | Initial issue | 68 | III-7 | C.E. Sanders | G. Radulescu | D.J. Tunney | S. Su | 8/14/03 |
| 00B | Update and revise the criticality safety evaluation of the DTF and RB. Revision includes new Boral loading for BWR assembly calculations, updated Category 1 and 2 event sequences, and inclusion of Y-12 review comments. Extensive Revision. All pages are affected. | 76 | III-8 | C.E. Sanders | D.S. Kimball | D.J. Tunney | S. Su | 3/02/04 |
| 00C | Update and revise the criticality safety evaluation of the DTF. Revision includes new DTF staging rack and remediation pool design as well as updated Category 1 and 2 event sequences. Extensive Revision. All pages are affected. | 79 | IV-1 | C.E. Sanders SIGNATURE ON FILE 05/17/2005 | J.M. Scaglione SIGNATURE ON FILE 5/17/05 | D.J. Tunney SIGNATURE ON FILE 5|17|2005 | W.E. Hutchins SIGNATURE ON FILE | 5-17-05 |

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## FIGURES

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## TABLES

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## 1. PURPOSE

This design calculation updates the previous criticality evaluation for the fuel handling, transfer, and staging operations to be performed in the Dry Transfer Facility (DTF) including the remediation area. The purpose of the calculation is to demonstrate that operations performed in the DTF and RF meet the nuclear criticality safety design criteria specified in the *Project Design Criteria (PDC) Document* (BSC 2004 [DIRS 171599], Section 4.9.2.2), the nuclear facility safety requirement in *Project Requirements Document* (Canori and Leitner 2003 [DIRS 166275], p. 4-206), the functional/operational nuclear safety requirement in the *Project Functional and Operational Requirements* document (Curry 2004 [DIRS 170557], p. 75), and the functional nuclear criticality safety requirements described in the *Dry Transfer Facility Description Document* (BSC 2005 [DIRS 173737], p. 3-8). A description of the changes is as follows:

- Update the supporting calculations for the various Category 1 and 2 event sequences as identified in the *Categorization of Event Sequences for License Application* (BSC 2005 [DIRS 171429], Section 7).

- Update the criticality safety calculations for the DTF staging racks and the remediation pool to reflect the current design.

This design calculation focuses on commercial spent nuclear fuel (SNF) assemblies, i.e., pressurized water reactor (PWR) and boiling water reactor (BWR) SNF. U.S. Department of Energy (DOE) Environmental Management (EM) owned SNF is evaluated in depth in the *Canister Handling Facility Criticality Safety Calculations* (BSC 2005 [DIRS 173284]) and is also applicable to DTF operations. Further, the design and safety analyses of the naval SNF canisters are the responsibility of the U.S. Department of the Navy (Naval Nuclear Propulsion Program) and will not be included in this document. Also, note that the results for the Monitored Geologic Repository (MGR) Site specific Cask (MSC) calculations are limited to the specific design chosen (see Assumption 3.4). A more current design will be included in the next revision of the criticality calculations for the Aging Facility. In addition, this calculation is valid for the current design as provided in Attachment III of the DTF and may not reflect the ongoing design evolution of the facility. However, it is anticipated that design changes to the facility layout will have little or no impact on the criticality results and/or conclusions presented in this document.

This calculation is subject to the *Quality Assurance Requirements and Description* (DOE 2004 [DIRS 171539]) because the DTF and the staging racks/baskets in the remediation pool are included as safety category items in the *Q-List* (BSC 2005 [DIRS 171190], pp. A-4 and A-7) as items important to safety. This calculation is prepared in accordance with AP-3.12Q, *Design Calculations and Analyses* [DIRS 168413].

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## 2. METHOD

### 2.1 CRITICALITY SAFETY ANALYSIS

The criticality safety calculations presented in this document evaluate fuel handling, transfer and staging operations in the DTF and remediation area to ensure they meet the criticality safety requirements under normal conditions as well as for Category 1 and 2 event sequences, in accordance with 10 CFR 63 [DIRS 173273]. Minimum spacing for PWR and BWR fuel storage racks in the DTF and remediation pool is determined along with varied neutron poison (Boral) panel thickness. The off-normal and accident conditions are inclusive of Category 1 and 2 event sequences as defined in 10 CFR 63.2 [DIRS 173273]. Moderator and reflector conditions are varied to find the most reactive configuration. The process and methodology for criticality safety analysis given in the *Preclosure Criticality Analysis Process Report* (BSC 2004 [DIRS 172058], Section 2.2.7) will be implemented in these calculations, and the following method will be followed:

- The criticality safety design of the facility will be based on the most reactive fuel.
- The effective neutron multiplication factor ($k_{eff}$), including all biases and uncertainties at a 95 % confidence level, will not exceed 0.95 under all credible normal, and Category 1 and 2 event sequences (NRC 2000 [DIRS 149756], Section 8.4.1.1).
- Conservative modeling assumptions leading to maximum reactivity for dimensional variables (e.g., pitch and manufacturing tolerances for assemblies) will be used.
- Conservative modeling assumptions will also be used regarding materials in the fuel including no accounting for burnable poisons in fuel, no credit for $^{234}U$ and $^{236}U$ in fuel, no credit for fission products or transuranic absorbers in fuel, and use of the most reactive fuel stack density.
- Fixed neutron absorbers used for criticality control can only take credit for up to 75% of the neutron absorbing content (NRC 2000 [DIRS 149756], Section 8.4.1.1).

Note that the terms "model(s)" and "modeling" as used in this calculation document refer to the geometric configurations of the criticality cases analyzed and not scientific models per LP-SIII.10Q-BSC, *Models* [DIRS 172972].

These calculations use the qualified software MCNP (CRWMS M&O 1998 [DIRS 154060]). MCNP is a three-dimensional Monte Carlo particle transportation code with the capability to calculate eigenvalues. The Nuclear Regulatory Commission (NRC) accepts MCNP in NUREG-1567 (NRC 2000 [DIRS 149756], p. 8-10) for criticality calculations.

### 2.2 ELECTRONIC MANAGEMENT OF INFORMATION

Electronic management of information generated from these calculations is controlled in accordance with Section 5.1.2 of AP-3.13Q, *Design Control* [DIRS 167460]. The computer input and output files generated from this calculation are stored on a Compact Disc (CD), and submitted as an attachment to this document (Attachment II).

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## 3. ASSUMPTIONS

### 3.1   LOADING OF STAGING RACKS AND POOL

*Assumption:* It is assumed that the DTF staging racks and remediation pool are full.

*Rationale*: In reality, the storage racks may not always be full.  However, for modeling purposes this should give maximum reactivity.

*Confirmation Status:* This assumption requires no further confirmation based on the stated rationale.

*Use in the Calculation:* Sections 5.1.4.1, 5.1.5.1, 5.2.1, and 5.2.2.

### 3.2   HYDRAULIC FLUID COMPOSITION

*Assumption:* It is assumed that the hydraulic fluid used as an alternative moderator material was a conventional silicone fluid (polysiloxane fluid) with a degree of polymerization of four (Gelest 2004 [DIRS 169915], p. 11).

*Rationale:* The basis for this assumption is that the DTF design has not identified the hydraulic fluid for lubrication, but the candidate material used for lubrication is expected to be less effective as a moderator than water.  The material used for this calculation to demonstrate criticality safety is a common silicone based hydraulic fluid (Gelest 2004 [DIRS 169915], p. 7). It should be recognized that this material might not represent the most reactive condition.  Any change in the design selection of the hydraulic fluid would require re-evaluation of criticality safety to ensure that all the criticality design criteria are met.

*Confirmation Status:* This assumption requires no further confirmation based on the stated rationale.

*Use in the Calculation:* Section 5.1.7.

### 3.3   WP BREACH

*Assumption*: It is assumed that a WP failure caused by drops and/or collisions is a non-credible event (i.e., beyond Category 2).

*Rationale*:  The primary mechanisms that can cause the WP to breach (e.g., drops or collisions) have been screened in *Categorization of Event Sequences for License Application* (BSC 2005 [DIRS 171429]), and show that drops onto sharp objects are beyond Category 2 (BSC 2005 [DIRS 171429], Table III-9), as well as collisions are beyond Category 2 (BSC 2005 [DIRS 171429], Table III-9). Therefore, it is reasonable to assume that a breach of a WP is a beyond Category 2 event.

*Confirmation Status:* This assumption requires no further confirmation based on the stated rationale.

*Use in the Calculation*: Section 6.3

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### 3.4    MSC DESIGN

*Assumption*: The Monitored Geologic Repository (MGR) Site specific Cask (MSC) is assumed to be similar in design, other than the neutron poison loading/configuration, to the Multi Purpose Canister (MPC)-24 for PWR fuel and the MPC-68 for BWR fuel that is part of the Holtec HI-STORM 100 cask system (Holtec International 2002 [DIRS 168494]).

*Rationale:* Since the MSC is still being developed, the criticality control features will be made similar to the existing NRC-certified storage casks.

*Confirmation Status:* This assumption requires no further confirmation based on the stated rationale.

*Use in the Calculation:* Sections 1, 6.3, and 6.4.

### 3.5    SELECTION OF REPRESENTATIVE TRANSPORTATION CASK

*Assumption:* It is assumed that the HI-STAR transportation cask is a representative and bounding cask for operations in the DTF.

*Rationale:* Performance requirement 3.1.1.3.1 of the *Transportation Cask Receipt/Return Facility Description Document* (BSC 2005 [DIRS 171702]) states that no decision has been made as to which transportation casks will be used.  However, the following approved casks by the NRC should be bounding for operations of CSNF: (1) GA-4; (2) HI-STAR; (3) NAC-UMS;  (4) TS-125; (5) NAC-STC; (6) NUHOMS-MP-187; (7) TN-68; and  (8) NUHOMS-MP-197. Tables 3.6-1 and 3.6-2 compare $k_{eff}$ values along with enrichment of the various transportation casks. It can be seen that the HI-STAR cask has one of the highest $k_{eff}$ values for PWR fuel and the highest $k_{eff}$ value for BWR fuel in addition to a relatively high enrichment. Therefore, HI-STAR is an acceptable choice for a representative cask for this calculation. The selection of this cask is bounding for normal conditions of transport under 10 CFR 71 [DIRS 171308].  Further evaluation should be made in future revisions of this calculation to address the applicability to repository conditions including normal operations and Category 1 and Category 2 conditions.

*Confirmation Status:* This assumption requires no further confirmation based on the stated rationale.

*Use in the Calculation:* Section 5.1.8.

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Table 3.6-1 Comparison of Most Reactive PWR Fuel in Various Transportation Casks

| Cask Type | PWR Fuel | | | | |
|---|---|---|---|---|---|
| | Fuel Type | Enrichment (wt% $^{235}$U) | $k_{eff}$ | St. Dev. | Reference |
| GA-4 | W 15x15 OFA | 3.15 | 0.9300 | 0.0011 | General Atomics 1998 [DIRS 103042], Table 6.4-2 |
| HI-STAR | B&W 15x15 | 4.1 | 0.9395 [a] | N/A | Holtec International 2003 [DIRS 172633], p. 6.2-27 |
| NAC-UMS | W 17x17 OFA | 4.2 | 0.9247 | 0.0009 | NAC International 2002 [DIRS 164612], Section 6.1 & Table 6.1-1 |
| TS-125 (W21 canister) | W 17x17 OFA | 4.6 | 0.94025 | 0.00093 | Sisley, S.E. 2002 [DIRS 171545], Table 6.4-6 |
| NAC-STC | Framatome-Cogema 17x17 | 4.5 | 0.92541 | 0.00086 | Thompson, T.C. 2003 [DIRS 169362], Section 6.1.1 |
| NUHOMS-MP-187 | B&W 15x15 | 3.43 | 0.9374 [b] | N/A | Transnuclear West 2002 [DIRS 161510], Table 6.1-1 & Table 6.2-1 |
| TN-68 | Not applicable to PWR fuel | | | | |
| NUHOMS-MP-197 | Not applicable to PWR fuel | | | | |

[a] maximum $k_{eff}$.
[b] $k_{eff}$ includes 2 standard deviations uncertainty.

Table 3.6-2 Comparison of Most Reactive BWR Fuel in Various Transportation Casks

| Cask Type | BWR Fuel | | | | |
|---|---|---|---|---|---|
| | Fuel Type | Enrichment (wt% $^{235}$U) | $k_{eff}$ | St. Dev. | Reference |
| GA-4 | Not applicable to BWR fuel | | | | |
| HI-STAR | GE 8x8 [a] | 4.2 | 0.9384 | 0.0007 | Holtec International 2003 [DIRS 172633], p. 6.2-36 |
| NAC-UMS | Exxon/ANF 9x9 | 4.0 | 0.9055 | 0.0008 | NAC International 2002 [DIRS 164612], Section 6.1 & Table 6.1-1 |
| TS-125 (W74 canister) | Siemens 11x11 | 4.1 | 0.93422 | 0.00089 | Sisley, S.E. 2002 [DIRS 171545], Table 6.4-10 |
| NAC-STC | Not applicable to BWR fuel | | | | |
| NUHOMS-MP-187 | Not applicable to BWR fuel | | | | |
| TN-68 | GE 10x10 | 3.7 | 0.9250 | 0.0008 | Transnuclear 2001 [DIRS 167988], Sections 6.1 & 6.4.2 |
| NUHOMS-MP-197 | GE 10x10 | 4.4 | 0.9349 | 0.0011 | Transnuclear 2002 [DIRS 160736], Sections 6.4.4 & 6.4.2 |

[a] Some other fuel assembly types have higher $k_{eff}$ values (see Section 5.1.2).

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### 3.6    SELECTION OF REPRESENTATIVE FUEL BASKET

*Assumption:* It is assumed that the fuel basket design used in both the HI-STAR and HI-STORM cask systems is a representative fuel basket design for staging operations in the DTF and remediation pool.

*Rationale:*   Storage rack cells, in the United States, designed to accommodate spent fuel are generally composed of stainless steel walls with a fixed neutron absorber panel (e.g., Boral) on each side (Wagner and Parks 2000 [DIRS 163140], p.7).  This is consistent with the fuel baskets featured in the Holtec cask systems. Therefore, it is acceptable to use the fuel basket design used in the HI-STAR/HI-STORM cask systems as a representative fuel basket for this calculation.

*Confirmation Status:* This assumption requires no further confirmation based on the stated rationale.

*Use in the Calculation:* Section 5.1.6.

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## 4. USE OF COMPUTER SOFTWARE

### 4.1 BASELINED SOFTWARE

#### 4.1.1 MCNP

The MCNP code (CRWMS M&O 1998 [DIRS 154060]) was used to calculate $k_{eff}$ for all systems presented in this report. The software specifications are as follows:

- Program Name: MCNP (CRWMS M&O 1998 [DIRS 154060])
- Version/Revision Number: Version 4B2LV
- Status/Operating System: Qualified/HP-UX B.10.20
- Software Tracking Number: 30033 V4B2LV
- Computer Type: HP 9000 Series Workstations
- CPU Number: 700887

The input and output files for the various MCNP calculations are contained on a CD (Attachment II) and the files are listed in Attachment I.

The MCNP software used was: (1) appropriate for the criticality ($k_{eff}$) calculations, (2) used only within the range of validation as documented through Briesmeister (1997 [DIRS 103897]) and CRWMS M&O (1998 [DIRS 102836]), and (3) obtained from Software Configuration Management in accordance with appropriate procedures.

### 4.2 COMMERCIAL OFF-THE-SHELF SOFTWARE

#### 4.2.1 MICROSOFT EXCEL 97 SR-2

- Title: Excel
- Version/Revision Number: Microsoft® Excel 97 SR-2
- This version is installed on a PC running Microsoft Windows 2000 with CPU number 503009

The file for the Excel calculation is contained on a CD (Attachment II) and the file is listed in Attachment I.

Excel was used to illustrate data in Section 6.3.2. Excel is exempt from qualification per Section 2.1.6 of LP-SI.11Q-BSC, *Software Management* [DIRS 171923].

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## 5. CALCULATION

All technical product inputs and sources of the inputs used in the development of this calculation are documented in this section. Attachment III features General Arrangement Drawings of the DTF and its remediation area as of the date of this calculation, and may not reflect the ongoing design evolution. The purpose of these drawings is to show the functional areas where the SNF will be handled and staged as well as to show the area where moderator control is required.

### 5.1 CALCULATIONAL INPUTS

### 5.1.1 Design Requirements and Criteria

The design criteria for criticality safety analysis provided in Section 4.9.2.2 of the *Project Design Criteria Document* (BSC 2004 [DIRS 171599]) are used in these calculations. The pertinent criteria for DTF criticality include the following (BSC 2004 [DIRS 171599], Section 4.9.2.2):

- The multiplication factor, $k_{eff}$, including all biases and uncertainty at a 95 percent confidence level, shall not exceed 0.95 under all normal conditions, and Category 1 and Category 2 event sequences.

- For fixed-neutron absorbers used for criticality control such as grid plates or inserts, no more than 75 percent credit of the neutron absorber content is used for preclosure criticality analyses, unless standard acceptance tests verify that the presence and uniformity of the neutron absorber are more effective.

- To use moderator control for nuclear criticality safety during preclosure for a facility, the facility shall limit the amount of moderator that may be present in any area where radioactive waste is being handled to show that there is no criticality concern under all normal conditions, Category 1 event sequences, and Category 2 event sequences.

The *Project Requirements Document* seeks to 'prevent unplanned nuclear criticality events' through requirement PRD-015/P-096 (Canori and Leitner 2003 [DIRS 166275], p. 4-206). From an operational/performance requirement point of view, 'the staging racks … shall be designed to maintain criticality safety' per the *Project Functional and Operational Requirements* document (Curry 2004 [DIRS 170557], Section 1.1.6-4). The functional requirement 3.2.3.1 of the *Dry Transfer Facility Description Document* (BSC 2005 [DIRS 173737], p. 3-8) states that the "design of the DTF spacing and neutron absorbers shall ensure that there is no credible criticality event under all normal conditions and Category 1 and 2 event sequences".

### 5.1.2 Fuel Assembly Selection

The Westinghouse 17x17 optimized fuel assembly (OFA) was chosen as a representative PWR fuel assembly for the DTF and remediation pool staging rack criticality calculations. The basket cell designs utilized in this calculation is that of the HI-STAR 100 cask system (Holtec International 2003 [DIRS 172633]). Studies have shown that either the B&W 15x15 or the Westinghouse 17x17 OFA (optimized fuel assembly) are the most reactive fuel assemblies inside the HI-STAR basket cells (Holtec International 2003 [DIRS 172633], p. 6.2-2). Therefore, the Westinghouse 17x17 OFA

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was chosen for the DTF and remediation area staging rack calculations. Evaluations of the HI-STAR transportation cask were also considered for Category 2 event sequences in the DTF. The Babcock & Wilcox (B&W) 15x15 fuel assembly (4.1 wt% enriched) was chosen as a representative fuel assembly inside the multi-purpose canister (MPC) for PWR fuel (note that MPC is a name of a component of the HI-STAR cask system). This is consistent with previously performed HI-STAR transportation cask calculations (BSC 2005 [DIRS 173616]).

The GE 8x8 fuel assembly was selected as representative of BWR fuel, because it is the most numerous design, inside the HI-STAR 100 basket cell design. Studies have shown that an 8x8 fuel array is one of the more reactive assembly configurations in the design inventory (Holtec International 2003 [DIRS 172633], Tables 6.2.20 – 6.2.36).  There is a 10x10 assembly design that produces a slightly higher $k_{eff}$ than the 8x8 fuel assembly (Table 6.2.32). However, this 10x10 fuel assembly design is not an actual assembly design, due to artificial bounding parameters for maximizing reactivity (Holtec International 2003 [DIRS 172633], p. 6.2-3), and was therefore not considered for this evaluation. A 9x9 fuel assembly design (Holtec International 2003 [DIRS 172633], Table 6.2.27) also produced a slightly higher $k_{eff}$ value than the selected 8x8 design. For completeness, one calculation was performed with this 9x9 fuel design in the staging racks to show the difference in calculated $k_{eff}$ values (see Section 6.1).

### 5.1.3    Upper Subcritical Limit

The upper subcritical limit (USL) is the value characterized by statistical tolerance limits that account for biases and uncertainties associated with the criticality code trending process, any uncertainties due to extrapolation outside the range of experimental data, or limitations in the geometrical or material representations used in the computational method, and an administrative margin-to-criticality that can reduce the actual critical limit.  The critical limit is a limiting value of $k_{eff}$ at which a configuration is considered potentially critical (BSC 2004 [DIRS 172058], Section 3.4.1).

The USL for CSNF (both PWR and BWR fuel) used in this calculation is 0.9472 as a limit in order to meet the design criteria that $k_{eff}$ shall not exceed 0.95 including bias and uncertainties at 95% confidence level (BSC 2004 [DIRS 171599], Section 4.9.2.2).  This number was calculated based on applicable code bias for similar fuel type and enrichment range of this analysis that has been estimated to be 0.0021 (value increased by truncation) with a standard deviation of $\pm 0.0007$ (Holtec International 2003 [DIRS 172633], Appendix 6.A-2). Consequently, the USL provides a margin of 0.0028 (0.95 – (0.0021+0.0007) = 0.9472) to account for code bias and uncertainties at 95% confidence level. Note that the uncertainties associated with the MCNP calculated $k_{eff}$ values are not included in the USL (see discussion in the last paragraph of this section).

All evaluations utilizing the HI-STAR/HI-STORM 100 cask system design are using worst case combination of manufacturing tolerances with respect to criticality determined by Holtec International (Holtec International 2003 [DIRS 172633], p. 6.3-2). The values presented in Sections 5.1.6.1, 5.1.6.2, and 5.1.8 of this document include the tolerances that maximize criticality potential. Evaluations have been performed to determine the effects of tolerances (Holtec International 2003 [DIRS 172633], Tables 6.3.1 & 6.3.2).  It was determined that design parameters important to criticality safety are fuel enrichment, the inherent geometry of the fuel basket structure and the fixed neutron absorbing panels (Boral) (Holtec International 2003 [DIRS 172633], p. 6.3-3).

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For preclosure, the USL criterion is used for comparison to predicted $k_{eff}$ values to determine a configuration's potential of exceeding the $k_{eff}$ limit that ensures subcriticality. In equation notation, the definition of the USL criterion is (BSC 2004 [DIRS 172058], Section 3.5):

$$k_S + \Delta k_S \leq USL \qquad (1)$$

where $k_S$ is the MCNP calculated value for the system, $\Delta k_S$ is an allowance for (a) statistical or convergence uncertainties, or both in the computation of $k_s$, (b) material and fabrication tolerances, and (c) uncertainties due to the geometric or material representations used in the computational method. Based on using a bounding representation in this calculation, items (b) and (c) were eliminated.

The uncertainty associated with the MCNP calculated value is accounted for by adding 2 times the standard deviation to the calculated $k_{eff}$ value and compare against USL. As an example, if the standard deviation associated with the MCNP calculated value for CSNF fuel is 0.00028 (see Section 6), the MCNP calculated value may not exceed 0.94664 (0.94664 + 2x0.00028=0.9472) in order to not violate the USL.

For a more detailed description of USL determination and criterion, see BSC 2004 [DIRS 172058] (Sections 3.4.1, 3.4.2, and 3.5).

### 5.1.4 DTF Staging Rack Calculation Inputs

The staging racks in the DTF were modeled as they are currently designed in accordance with Attachment III.  Physical inputs for the staging racks are described in the following subsection.

### 5.1.4.1    DTF Staging Rack Configuration and Physical Dimensions

The various layout plans considered for the staging tubes are shown in Attachment IV. The staging rack configuration for the DTF PWR and BWR fuel assemblies for this calculation consists mainly of a 9 x 11 array of 16 in. (outside diameter) single staging tubes. The tubes were modeled with 0.5 in. thickness of stainless steel. A sensitivity study was performed with a 1.0 in. thick stainless steel tube (the distance between assemblies was maintained the same) to ensure that a varied thickness would not impact the $k_{eff}$ values (see results in Section 6.1). The spacing between the tubes has not been determined (that is part of this evaluation), and the different spacing distances considered are 10 in., 12 in., and 16 in. of concrete between the tubes. The calculation considers the full length of the spacing between the tubes to consist of concrete. It should be mentioned that the current design plans do not include concrete for the full length (only approximately the top 5 ft).  However, including the full length of concrete in the MCNP model will be conservative from a criticality perspective. In addition to the 9 x 11 array configuration, the 10 in. concrete spacing also considers a 10x12 array configuration with staggered lines (triangular pitch). Attachment IV displays the various layout plans and the dimensions.

For conservatism in criticality safety analysis, the MCNP models of the DTF fuel staging racks are always modeled as full (Assumption 3.1). In addition, only the active fuel region is modeled in the MCNP models (the active fuel length is extended slightly to cover the end-fittings regions).  A

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previous study has shown that the fuel rod can be modeled either with or without end-regions included for criticality calculations (BSC 2005 [DIRS 173616], Table 5.2-1). The DTF staging tube was modeled with a length of 27 ft and the top of the tube beginning 5 ft below the floor, comprising a total length of 32 ft. The total length was estimated from the General Arrangement Drawing presented in Attachment III, p. III-24. The area below the staging tube, that holds the fuel assembly, was modeled as a stainless steel structure.

### 5.1.5    Remediation Pool Calculation Inputs

The pool in the RF was modeled per the current design as shown in Attachment III. Physical inputs for the RF pool are described in the following subsection.

### 5.1.5.1 Remediation Pool Configuration and Physical Dimensions

The remediation pool allows for 14 staging racks placed in 2 rows in accordance with p. III-13 of Attachment III.  Each staging rack is 3'-4"x 3'-4" and can hold a 3x3 array of PWR fuel assemblies and a 4x4 array of BWR fuel assemblies (Cogema 2003 [DIRS 167153]). The width of the pool is 59 ft. and 3 in. and the pool along with the crane maintenance platform is 55 ft. deep (Cogema 2004 [DIRS 173297]). To minimize neutron leakage and account for reflection, the pool itself was modeled as 55 ft deep whereof 5 ft is a bottom steel plate. The maximum spacing of the first to last staging rack in one row is limited to 35'-1" due to travel capacity of the bridge crane (Cogema 2004 [DIRS 173297).  In addition, the stainless steel liner surrounding the pool is 5 ft. wide (BSC 2004 [DIRS 170728]). As with the DTF staging rack, the MCNP models of the staging racks in the remediation pool are always modeled as full (Assumption 3.1). In addition, only the active fuel region is modeled in the MCNP models (the active fuel length is extended slightly to cover the end-fittings regions).

### 5.1.6    Basket Cell and Fuel Assembly Calculation Inputs

Since a final design of the basket cells contained in the staging racks has not been selected, the HI-STAR 100 cask system cell baskets were utilized (Assumption 3.6). The following sub-sections describe the basket cell geometry and the fuel assembly dimensions.

### 5.1.6.1    PWR Basket Cell and Fuel Assembly Dimensions

The PWR fuel cell basket features SS walls with a Boral panel situated on each side. The PWR fuel cell basket contains a Westinghouse 17 x 17 OFA (Section 5.1.2). Figure 5.1-1 displays the cell basket with the Westinghouse 17 x 17 OFA and Table 5.1-1 features the dimensions of the cell basket.  Table 5.1-2 displays the specifications of the PWR fuel assembly.

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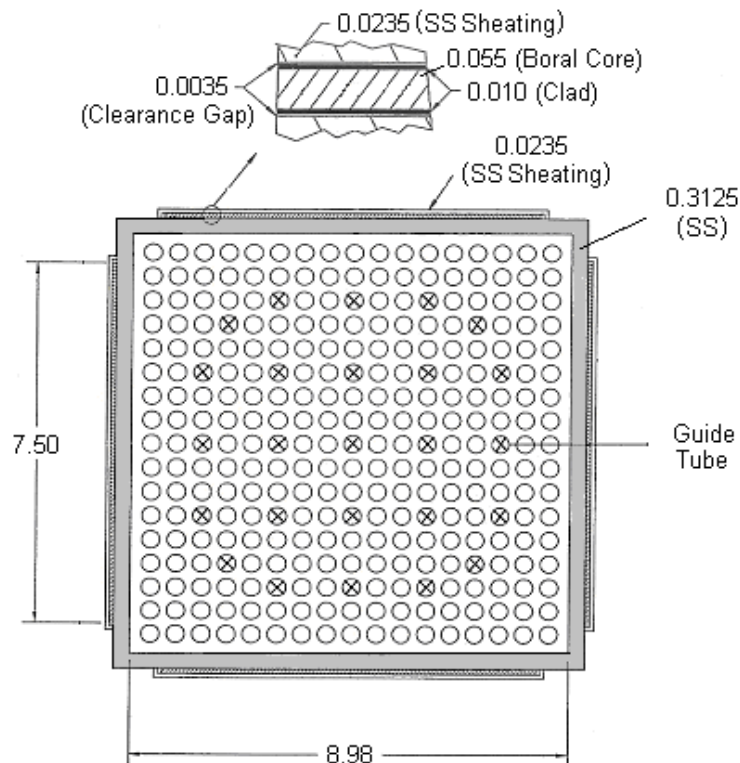
NOTE: Dimensions are in inches. Figure is not to scale.

Figure 5.1-1 PWR Fuel Basket Cell Containing Westinghouse 17 x 17 OFA
(Source: Holtec International 2003 [DIRS 172633], Figure 6.3.1)

Table 5.1-1 Radial Dimensions of the Basket Cell Geometry

| Component | Dimension (cm) | Reference |
|---|---|---|
| Cell box inside dimension | 22.8092 (8.98 in.) | Holtec International 2003 [DIRS 172633], Table 6.3.3 |
| Cell pitch | 27.7012 (10.906 in.) | Holtec International 2003 [DIRS 172633], Table 6.3.3 |
| Cell wall thickness (SS) | 0.79375 (0.3125 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.1 |
| SS sheathing | 0.05969 (0.0235 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.1 |
| Boral thickness | 0.1397 (0.055 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.1 |
| Al thickness (Clad) | 0.0254 (0.010 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.1 |
| Boral width | 19.05 (7.50 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.1 |
| Boral clearance gap | 0.00889 (0.0035 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.1 |

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Table 5.1-2 Specifications of the PWR W 17 x 17 OFA

| Parameter | Dimension (cm) | Reference [b] |
|---|---|---|
| Rod pitch | 1.2598 (0.496 in.) | Holtec International 2002 [DIRS 168494], p. 2.1-11 |
| Active fuel length | 381.0 (150.0 in.) | Holtec International 2002 [DIRS 168494], p. 2.1-11 |
| Cladding outside diameter | 0.9144 (0.360 in.) | Holtec International 2002 [DIRS 168494], p. 2.1-11 |
| Cladding inside diameter | 0.8001 (0.315 in.) | Holtec International 2002 [DIRS 168494], p. 2.1-11 |
| Pellet outside diameter | 0.784352 (0.3088 in.) | Holtec International 2002 [DIRS 168494], p. 2.1-11 |
| Guide/instrument tube outside diameter | 1.204 | Sanders and Wagner 2002 [DIRS 163141], p.8 |
| Guide/instrument tube thickness | 0.04064 (0.016 in.) | Holtec International 2002 [DIRS 168494], p. 2.1-11 |
| Array size | 17 x 17 | Holtec International 2002 [DIRS 168494], p. 2.1-11 |
| Number of fuel rods | 264 | Holtec International 2002 [DIRS 168494], p. 2.1-11 |
| Number of guide/instrument tubes [a] | 25 | Holtec International 2002 [DIRS 168494], p. 2.1-11 |

[a] Locations of guide tubes are shown in Figure 5.1-1.
[b] Holtec International 2002 [DIRS 168494], p. 6.2-37 demonstrates that the dimensions cited are conservative


### 5.1.6.2    BWR Basket Cell and Fuel Assembly Dimensions

The BWR fuel cell basket features SS walls with a Boral panel situated on the top and on the left hand side. The BWR fuel cell basket contains the GE 8x8 assembly (see Section 5.1.2). Figure 5.1-2 displays the basket cell with the GE 8x8 assembly. Table 5.1-3 provides the radial dimensions of the basket cell while Table 5.1-4 displays the specifications of the 8x8 BWR fuel assembly.

For completeness, one calculation was also performed for a 9x9 fuel array arrangement to ensure criticality safety and most reactive BWR fuel configuration (see Section 5.1.2). Table 5.1-5 displays the specifications of the 9x9 BWR fuel assembly.

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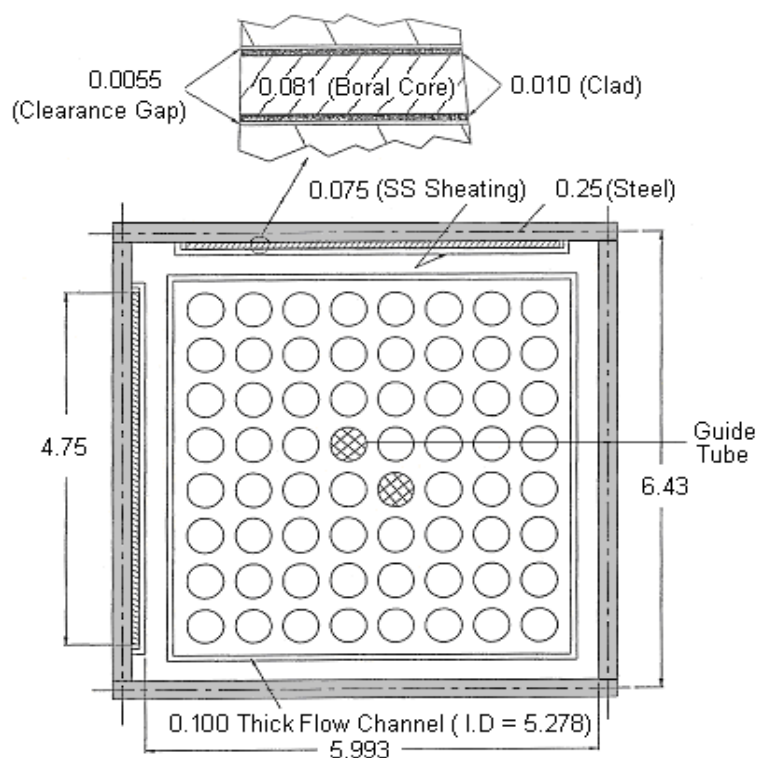
NOTE: Dimensions are in inches. Figure not to scale.

Figure 5.1-2 BWR Fuel Basket Cell Containing GE 8x8 Assembly
(Source: Holtec International 2003 [DIRS 172633], Figure 6.3.3)

Table 5.1-3 Radial Dimensions of the BWR Basket Cell

| Component | Dimension (cm) | Reference |
|---|---|---|
| Cell box inside dimension | 15.2222 (5.993 in.) | Holtec International 2003 [DIRS 172633], Table 6.3.3 |
| Cell pitch | 16.3322 (6.43 in.) | Holtec International 2003 [DIRS 172633], Table 6.3.3 |
| Cell wall thickness (SS) | 0.635 (0.25 in.) | Holtec International 2003 [DIRS 172633], Table 6.3.3 |
| SS sheathing | 0.1905 (0.075 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.3 |
| Boral thickness | 0.2057 (0.081 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.3 |
| Al thickness (Clad) | 0.0254 (0.010 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.3 |
| Boral width | 12.065 (4.75 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.3 |
| Boral clearance gap | 0.01397 (0.0055 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.3 |
| Flow channel thickness | 0.254 (0.100 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.3 |

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Table 5.1-4 Specifications of the BWR GE 8 x 8 Standard Assembly

| Parameter | Dimension (cm) | Reference |
|---|---|---|
| Rod pitch | 1.6256 (0.640 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.22 |
| Active fuel length | 381.0 (150 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.22 |
| Cladding outside diameter | 1.2268 (0.483 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.22 |
| Cladding inside diameter | 1.0796 (0.425 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.22 |
| Pellet outside diameter | 1.0566 (0.416 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.22 |
| Guide tube (Thimble) outside diameter | 1.3488 | Holtec International 2003 [DIRS 172633], p. 6.D-15 |
| Guide tube (Thimble) thickness | 1.5012 | Holtec International 2003 [DIRS 172633], p. 6.D-15 |
| Array size | 8 x 8 | Holtec International 2003 [DIRS 172633], Table 6.2.22 |
| Number of fuel rods | 62 | Holtec International 2003 [DIRS 172633], Table 6.2.22 |
| Number of guide/instrument tubes [a] | 2 | Holtec International 2003 [DIRS 172633], Table 6.2.22 |

[a] Locations of guide tubes are shown in Figure 5.1-2.


Table 5.1-5 Specifications of the BWR 9 x 9 Assembly

| Parameter | Dimension (cm) | Reference |
|---|---|---|
| Rod pitch | 1.45288 (0.572 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.27 |
| Active fuel length | 381.0 (150 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.27 |
| Cladding outside diameter | 1.09982 (0.433 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.27 |
| Cladding inside diameter | 0.96774 (0.381 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.27 |
| Pellet outside diameter | 0.94996 (0.374 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.27 |
| Array size | 9 x 9 | Holtec International 2003 [DIRS 172633], Table 6.2.27 |
| Number of fuel rods | 72 | Holtec International 2003 [DIRS 172633], Table 6.2.27 |
| Number of guide/instrument tubes [a] | 1 | Holtec International 2003 [DIRS 172633], Table 6.2.27 |

[a] This tube replaces the space of 9 fuel rods.


### 5.1.7    Material Compositions

This section presents the material compositions for the PWR and BWR fuel along with the cell basket, DTF staging racks, and the remediation pool. The calculations were performed with either the isotopic compositions given in weight fraction, weight percent (wt%), or atom densities (atoms/barn-cm) depending on the source of the input. Table 5.1-6 displays the relevant materials used for the staging racks and the fuel.

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Per Assumption 3.2, Polysiloxane fluid was chosen as an alternate moderator material (in the event hydraulic fluid/oil leak from a handling crane). Polysiloxane fluid was modeled with a density of 0.9 g/cm$^3$ (Gelest 2004 [DIRS 169915], p. 11). The chemical formula for this fluid is
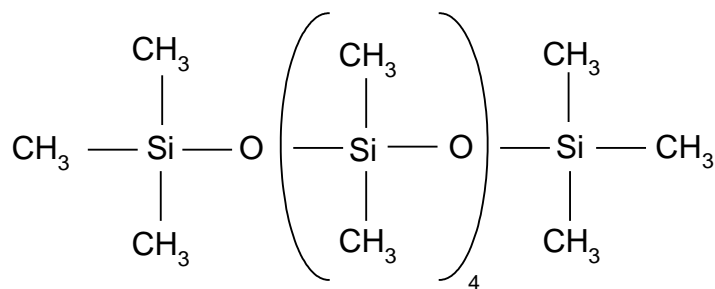


Source: (Gelest 2004 [DIRS 169915], p. 11)

Table 5.1-6 Material Properties for the Staging Racks and Fuel

| Material | Density (g/cm$^3$) | Element | Weight Fraction or Weight Percent (wt %) | Atom Fraction or Atom Density (atoms/barn-cm) | Reference/ Remark |
|---|---|---|---|---|---|
| H$_2$O (throughout model) | 1.0 | H O | N/A | 6.688E-02 [c] 3.344E-02 [c] | Holtec International 2003 [DIRS 172633], Table 6.3.4 |
| SS (tube, cell wall & reflector) | 7.84 | Cr Mn Fe Ni | N/A | 1.761E-02 1.761E-03 5.977E-02 8.239E-03 | Holtec International 2003 [DIRS 172633], Table 6.3.4 |
| Al (Boral panel) | 2.7 | Al | 1.0 | N/A | Holtec International 2003 [DIRS 172633], Table 6.3.4 |
| Boral (0.02 g $^{10}$B/cm$^2$) [a] | 2.66 | B-10 B-11 C Al | 5.443E-02 2.414E-01 8.210E-02 6.222E-01 | N/A | Holtec International 2003 [DIRS 172633], Table 6.3.4 |
| UO$_2$ – (fuel) 5.00 % enriched | 10.522 | U-235 U-238 O-16 | 4.408 83.74 11.85 | N/A | Holtec International 2002 [DIRS 168494], p. 6.3-9 |
| UO$_2$ – (fuel) 4.10 % enriched [b] | 10.522 | U-235 U-238 O-16 | 3.6140 84.536 11.850 | N/A | Average value taken from Holtec International 2003 [DIRS 172633], Table 6.3.4 of 4.0 % and 4.2 % enrichment |
| Zr (Cladding) | 6.55 | Zr | 100 | N/A | Holtec International 2003 [DIRS 172633], Table 6.3.4 |
| Concrete (floor & reflector material) | 2.147 | Fe, H, C, Na, O, Mg, Al, Si, S, Cl, K, Ca, Ti, Mn | 0.5595, 0.3319, 10.5321, 0.1411, 49.9430, 9.4200, 0.7859, 4.2101, 0.2483, 0.0523 [d], 0.9445, 22.6318, 0.1488, 0.0512 [d] | N/A | Petrie, L. M. et. al. 2000 [DIRS 170550], p. M8.2.28 |

[a] The $^{10}$B loading of 0.020 g/cm$^2$ is 75 % of the minimum loading 0.0267 g/cm$^2$ (Holtec International 2003 [DIRS 172633], p. 6.2-2)

[b] Used for HI-STAR transportation cask calculations (Section 5.1.8)

[c] Fractions of 0.6667 and 0.3333 used in MCNP input

[d] 0.0520 used in MCNP input instead of 0.0523 and 0.0510 used instead of 0.0512

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### 5.1.8    Category 1 and 2 Event Sequence Evaluations Input Description

Evaluations of Category 2 event sequences used the HI-STAR transportation cask (Assumption 3.5). B&W 15x15 fuel assembly at 4.1 wt% enrichment was used as a representative fuel (see Section 5.1.2) and the transportation cask was modeled in MCNP in accordance with the *HI-STAR 100 Transport Cask Safety Analysis Report* (Holtec International 2003 [DIRS 172633], Section 6.3). The physical dimensions and material compositions of the transportation cask and fuel are documented in BSC 2005 [DIRS 173616], Section 5.1.6. The MPC-24 for pressurized water reactor (PWR) fuel consists of a stainless steel (SS) cask/overpack and an interior 24 PWR assembly basket. Figure 5.1-3 displays the planar cross-section of the MPC-24 calculational model inside the overpack and Figure 5.1-4 presents the axial view. Table 5.1-7 provides the radial and axial dimensions of the MPC-24 and overpack. The material composition of the B&W 15x15 fuel is shown in Table 5.1-6 and the dimensions are shown in Table 5.1-8.
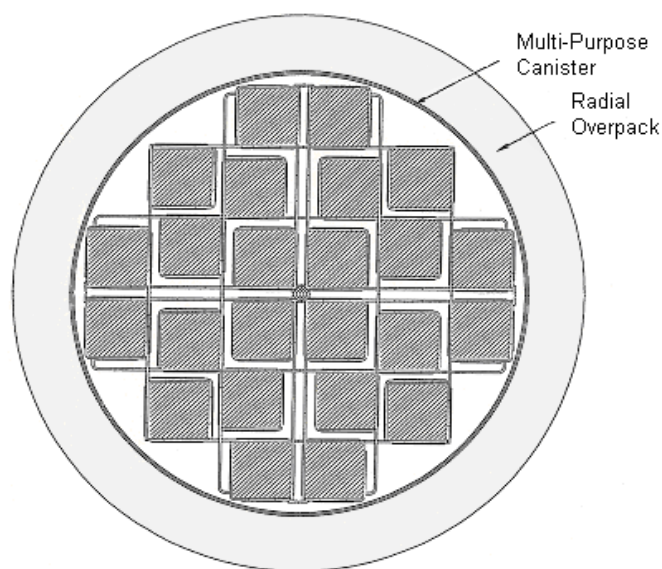


NOTE: Figure not to scale.

Figure 5.1-3 Radial View of the MPC-24 and Overpack
(Source: Holtec International 2003 [DIRS 172633], Figure 6.3.4)

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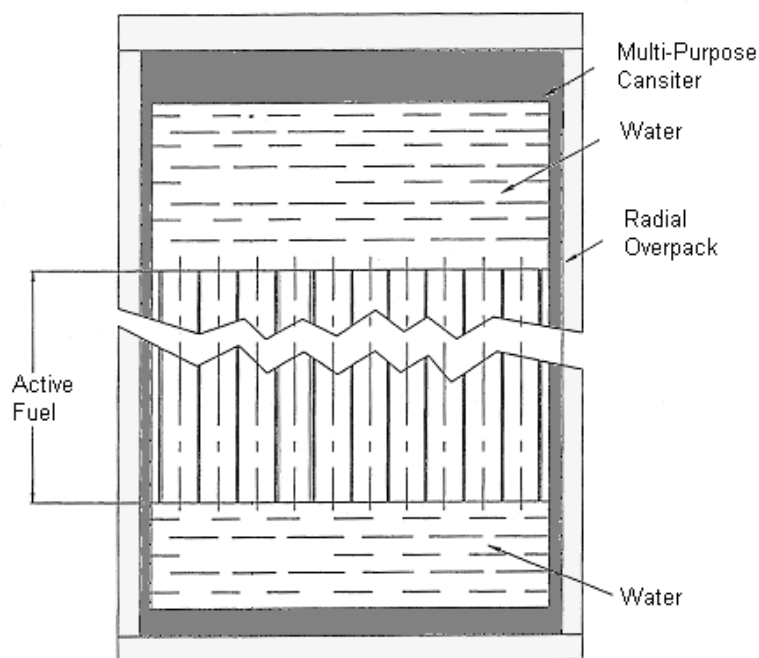
NOTE: Figure is not to scale.

Figure 5.1-4 Axial View of the MPC-24 PWR Fuel Transportation Cask
(Source: Holtec International 2003 [DIRS 172633], Figure 6.3.7)

Table 5.1-7 Dimensions of the MPC-24, Overpack, and Cell Geometry

| Component [b] | Dimension (cm) | Reference |
|---|---|---|
| Stainless steel (SS) overpack thickness | 22.86 (9.00 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.4 |
| SS overpack, i.d. | 171.1325 (67.375 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.4 |
| Center column | 6.985 (2.75 in.) | Holtec International 2003 [DIRS 172633], Drawing 3926 (Sheet 2) |
| Flux trap | 2.7686 (1.09 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.1 & Table 6.3.3 |
| Boral width – narrow [a] | 15.875 (6.25 in.) | Holtec International 2003 [DIRS 172633], Drawing 3926 (Sheet 2) |
| Lower water thickness (below active fuel region) | 10.16 (4.0 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.7 |
| Upper water thickness (above active fuel region) | 15.24 (6.0 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.7 |
| Bottom overpack SS plate thickness | 21.59 (8.5 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.7 |
| Top overpack SS plate thickness | 39.37 (15.5 in.) | Holtec International 2003 [DIRS 172633], Figure 6.3.7 |

[a] The periphery Boral panels have reduced width. See Table 5.1-1 for regular Boral panel width.
[b] See Table 5.1-1 for additional dimensions.

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Table 5.1-8 Specifications of the PWR B&W 15 x15 Assembly

| Parameter | Dimension (cm) [a] | Reference |
|---|---|---|
| Rod pitch | 1.4428 (0.568 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Active fuel length | 381.0 (150 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Cladding outside diameter | 1.0872 (0.428 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Cladding thickness | 0.05842 (0.023 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Pellet outside diameter | 0.9504 (0.3742 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Guide/instrument tube outside diameter | 1.3412 (0.528 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Guide/instrument tube inside diameter | 1.27 (0.50 in.) | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Array size | 15 x 15 | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Number of fuel rods | 208 | Holtec International 2003 [DIRS 172633], Table 6.2.2 |
| Number of guide/instrument tubes [b] | 17 | Holtec International 2003 [DIRS 172633], Table 6.2.2 |

[a] Some of the values are rounded up slightly.
[b] Locations of guide tubes are shown in Holtec International 2003 [DIRS 172633], Figure 6.3.2.

To evaluate the impact of fuel reconfiguration on $k_{eff}$ under dry and fully flooded moderator conditions for Category 1 and 2 event sequences, a simplified pin cell model was utilized. The calculations used 5 wt% fresh fuel initial enrichment with Westinghouse 17x17 OFA and GE 7x7 fuel assembly types for PWR and BWR fuel, respectively. Note that the pin cell model was only used to study trends and not to produce absolute $k_{eff}$ values. Therefore, a different BWR fuel type was used for the pin cell model since the pin cell model has already been used in previous calculations. Table 5.1-9 lists the PWR and BWR fuel considered and their fuel parameters. Figure 5.1-5 displays a cross-sectional view of the pin cell model used for this analysis.

Table 5.1-9 Fuel Types Used for Fuel Reconfiguration Evaluation and their Fuel Parameters

| PWR fuel | | | | | | |
|---|---|---|---|---|---|---|
| Manufacturer | Array and Version | Pin pitch [a] (cm) | Clad o.d. [a] (cm) | Clad thickness (cm) | Pellet diameter [a] (cm) | U-235 wt % enrichment |
| Westinghouse | 17x17 OFA | 1.25984 | 0.91440 | 0.05715 [b] | 0.784352 | 5.00 |
| **BWR fuel** | | | | | | |
| GE | 7x7 Std | 1.87452 | 1.43002 | 0.08128 [c] | 1.23698 | 5.00 |

[a] Source: General Atomics 1993 [DIRS 101831], p. 6.2-2
[b] Source: DOE 1987 [DIRS 132333], p. 2A-351
[c] Source: DOE 1992 [DIRS 102812], p. 2A-15 and 2A-16

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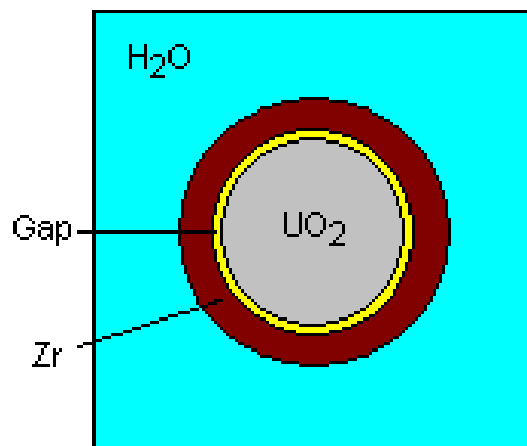
Figure 5.1-5 Cross-section View of Pin Cell Model

## 5.2    CRITICALITY CALCULATIONS

The process and methodology for criticality safety analysis given in the *Preclosure Criticality Analysis Process Report* (BSC 2004 [DIRS 172058], Section 2.2.7) was implemented in these calculations. This process and methodology requires, as stated earlier in Section 2, consideration of the most reactive fuel assembly, the effective neutron multiplication factor will not exceed 0.95 including all uncertainties and bias, no burnup credit, and no credit for $^{234}$U and $^{236}$U. Further, all calculations were performed with flooded fuel pin gaps except for dry moderator conditions, 5 wt% fresh fuel, and only 75 % credit for the fixed neutron absorber was applied.

### 5.2.1  DTF Staging Rack Calculations

Water moderator density, which could vary from dry to fully moderated conditions under accident conditions, was considered dry (0 % density water) and fully moderated (100 % density water) in the DTF staging racks. Hydraulic fluid/oil was also evaluated as an alternate moderator since it could possibly leak from a handling crane. Further, additional steel was included inside the steel tube (surrounding the fuel assembly) to be evaluated as a possible reflector.

Different spacings between the tubes were considered to allow room for reinforcing steel in the concrete slab. As mentioned in Section 5.1.4.1, the spacings considered are 10 in., 12 in., and 16 in. of concrete between the 9x11 array of tubes. For the 10 in. spacing scenario, a triangular pitch (staggered rows as opposed to straight rows) was also considered in a 10x12 array (see Attachment IV).

Per Assumption 3.1, the tubes in the DTF staging rack are modeled in MCNP as full (i.e., every available tube in the array is filled with an assembly).

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### 5.2.2    Remediation Pool

The PWR and BWR storage rack configurations for the remediation pool were analyzed for various assembly pitches and 5.0 wt % enrichment in order to ensure that the configuration meets design criteria (BSC 2004 [DIRS 171599], Section 4.9.2.2).  The various distances/pitches evaluated consist of a nominal scenario and a close spacing scenario.  The nominal scenario spacing is based on the maximum traveling distance of the bridge crane (see Section 5.1.5.1) while the close spacing scenario spacing represents assemblies and staging racks more closely situated. The nominal arrangement distances for the staging racks are approximately 11 in. in the x-direction with the two rows of staging racks at approximately 39 in. apart (in the y-direction). The BWR assemblies inside each staging rack have an equal spacing of 3.2 in. (both in the x and y directions) and the PWR assemblies have an equal spacing of 4.0 in. (both in the x and y directions). The close spacing scenario feature arrangement distances for the staging racks at approximately 11 in. in the x-direction with the two rows of staging racks at approximately 3 in. apart (in the y-direction). The BWR assemblies inside each staging rack, for the close spacing scenario, have an equal spacing of 0.4 in. (both in the x and y directions) and the PWR assemblies have an equal spacing of 2.0 in. (both in the x and y directions). It should be mentioned that the distances in the x-direction between the staging racks vary slightly for both the nominal and close spacing scenario but will not impact the results significantly. The reason for this is that the spacings presented above represents the maximum distance between the staging racks and will ensure that the results presented in Section 6 are conservative.

As mentioned in Section 5.1.5.1, the staging rack can hold a 3x3 array for PWR fuel or a 4x4 array for BWR fuel. Per Assumption 3.1, the staging racks in the remediation pool are modeled in MCNP as full.

The neutron poison (e.g., Boral) loadings evaluated were for 0 g $^{10}$B/cm$^2$ and 0.02 g $^{10}$B/cm$^2$. In addition, the thickness of the Boral plate was reduced to half its width in the MCNP model for the 0.02 g $^{10}$B/cm$^2$ scenario.

### 5.2.3    Category 1 and 2 Event Sequences

The Category 1 and Category 2 event sequences applicable to the DTF and its remediation area have been identified in the *Categorization of Event Sequences for License Application* document (BSC 2005 [DIRS 171429], Section 7). Category 1 event sequences are presented in Table 5.2-1 and Category 2 event sequences are presented in Table 5.2-2. The supporting calculations for the event sequences are provided in Section 6.3.

Table 5.2-1 Category 1 Event Sequences

| Event No. | Event      Description | Annual Event Frequency | Reference |
|---|---|---|---|
| GET-03D | Drop of a CSNF assembly | 0.5 drops/y | BSC 2005 [DIRS 171429], Section 7 |
| GET-03B | Collision involving a CSNF assembly | 0.5 collisions/y | |

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Table 5.2-2 Category 2 Event Sequences

| Event No. | Event Description | Expected Occurrence | Reference |
|---|---|---|---|
| GET-01A | Drop of a transportation or transfer cask without impact limiters | 5.7E-01 | |
| GET-02B | Drop of inner lid of a transportation or transfer cask, MSC, or WP into a transportation cask, MSC, or WP | 5.7E-01 | |
| GET-03E | Drop of a CSNF assembly during transfer combined with HVAC failure | 9.7E-02 | |
| GET-03C | Collision involving a CSNF assembly during transfer combined with HVAC failure | 9.7E-02 | |
| GET-04B | Drop or collision of handling equipment onto a CSNF assembly | 9.7E-02 | |
| GET-05B | Drop of a canister during transfer by crane | 5.7E-01 | |
| GET-06B | Drop of handling equipment onto a canister | 5.7E-01 | |
| GET-07B | Drop of an unsealed WP | 8.6E-02 | |
| GET-09C | Drop of a WP with a known closure defect | 2.6E-02 | |
| GET-10C | Drop of a CSNF assembly during dry remediation activities | 4.9E-01 | |
| GET-10B | Collision involving a CSNF assembly during dry remediation activities | 4.9E-01 | |
| GET-11B | Drop of a canister from a crane during WP remediation or dry remediation activities | 5.7E-02 | |
| GET-12B | Drop of CSNF assembly transfer/handling equipment onto CSNF assemblies in the DTF remediation pool | 4.9E-03 | BSC 2005 [DIRS 171429], Section 7 |
| GET-13A | Drop of a loaded transportation cask or MSC in the DTF wet remediation area | 1.1E-01 | |
| GET-15C | Drop of an empty or full canister for damaged CSNF assemblies (empty or full) onto or against a cask or basket in the DTF remediation pool | 4.9E-02 | |
| GET-15B | Collision of an empty or full canister for damaged CSNF assemblies (empty or full) onto or against a cask or basket in the DTF remediation pool | 4.9E-02 | |
| GET-16C | Drop of a CSNF assembly in the DTF remediation pool | 4.9E-01 | |
| GET-16B | Collision involving a CSNF assembly in the DTF remediation pool | 4.9E-01 | |
| GET-17B | Drop of a filled SNF basket from the spent fuel transfer machine onto the DTF remediation pool floor | 5.4E-02 | |
| GET-18B | Drop of handling equipment into or against an opened WP filled with CSNF during dry remediation activities | 4.9E-03 | |
| GET-19B | Drop of handling equipment into an open WP loaded with DOE canisters or a naval canister during dry remediation activities | 3.6E-02 | |
| GET-20B | Drop of a severed DPC lid back onto the DPC | 1.0E-01 | |

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## 6.  RESULTS AND CONCLUSIONS

This section presents the results of the criticality calculations and makes recommendations for additional criticality safety design features as appropriate.  The outputs presented in this document are all reasonable compared to the inputs and the results are suitable for the intended use.  The uncertainties are taken into account by consistently using a conservative approach, which is the result of the methods and assumptions described in Sections 2 and 3, respectively.

### 6.1   DTF STAGING RACK

The concrete spacing between the tubes containing the staging racks with PWR fuel was altered in order to ensure criticality safety under the most reactive configuration.  The scenarios considered include a fully flooded 9x11 tube array (straight lines) with 10 in., 12 in., and 16 in. spacing, respectively (see Section 5.2.1).  Further, the 10 in. concrete spacing was also repeated for a 10x12 fully flooded tube array with a triangular pitch (staggered lines) as opposed to the regular square pitch. None of these calculations include fixed neutron poison.  The results from the calculations are presented in Table 6.1-1.  It can be seen from the results that each spacing and pitch scenario meets the criticality safety criteria.  In addition, $k_{eff}$ is not sensitive to the thickness of the stainless steel tube (see first and second entries in Table 6.1-1).  Note that the distance between assemblies was maintained the same for the two calculations where the stainless steel thicknesses were varied.  Consequently, there is only 9 in. of concrete between the tubes and 1 in. of stainless steel for the calculation with the thicker tube (second entry in Table 6.1-1).

Table 6.1-1 PWR Fuel in Various DTF Staging Tube Configurations (w/o Neutron Poison)

| DTF Staging Tube Configuration | $k_{eff}$ | St. Dev. | MCNP files |
|---|---|---|---|
| 10 " concrete spacing square pitch (9x11 array) | 0.91008 | 0.00028 | DTF10pwr, DTF10pwr.out |
| 10 " spacing square pitch (9x11 array) [a] | 0.90996 | 0.00029 | DTF10p10, DTF10p10.out |
| 10 " concrete spacing triangular pitch (10x12 array) | 0.90958 | 0.00030 | DTF10tri, DTF10tri.out |
| 12 " concrete spacing square pitch (9x11 array) | 0.90920 | 0.00027 | DTF12pwr, DTF12pwr.out |
| 16 " concrete spacing square pitch (9x11 array) | 0.90788 | 0.00030 | DTF-pwr1, DTF-pwr1.out |

[a] This calculation has a steel tube thickness of 1.0 in. (nominal thickness is 0.5 in.).

Table 6.1-2 shows the $k_{eff}$ for a fully flooded 9x11 tube array (straight lines) with 16 in. of concrete spacing for PWR and BWR fuel. The cases containing fixed neutron poison (i.e., Boral) has a loading of 0.02 g $^{10}$B/cm$^2$ (regular width). Note that the table contains one BWR calculation using a 9x9 fuel assembly.  It can be seen that it is only slightly more reactive than the 8x8 fuel assembly used throughout this calculation.

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Table 6.1-2 PWR and BWR Fuel in DTF Staging Tubes (16 in. Spacing)

| DTF Staging Rack Configuration | $k_{eff}$ | St. Dev. | MCNP files |
|---|---|---|---|
| **PWR Fuel** | | | |
| 16 " concrete spacing no neutron poison present | 0.90788 | 0.00030 | DTF-pwr1, DTF-pwr1.out |
| 16 " concrete spacing neutron poison present | 0.85366 | 0.00029 | DTF-pwr, DTF-pwr.out |
| **BWR Fuel** | | | |
| 16 " concrete spacing no neutron poison present | 0.61263 | 0.00027 | DTF1-bwr1, DTF-bwr1.out |
| 16 " concrete spacing no neutron poison present [a] | 0.61927 | 0.00027 | DTF1-9x9, DTF1-9x9.out |
| 16 " concrete spacing neutron poison present | 0.56718 | 0.00027 | DTF-bwr, DTF-bwr.out |

[a] Featuring a 9x9 fuel array configuration

Various moderator and reflector conditions were evaluated for PWR and BWR fuel in the DTF staging racks. The 9x11 tube array (straight lines) with 16 in. of concrete spacing model was used with no fixed neutron poison present.

Table 6.1-3 PWR and BWR Fuel in DTF Staging Tubes with Varied Moderator and Reflector Conditions

| Reflector/Moderator Material | $k_{eff}$ | St. Dev. | MCNP files |
|---|---|---|---|
| **PWR Fuel** | | | |
| Oil (moderator) | 0.80101 | 0.00028 | DTFopwr1, DTFopwr1.out |
| Void (moderator) | 0.24831 | 0.00012 | DTF-pwr0, DTF-pwr0.out |
| Steel (reflector) [a] | 0.16869 | 0.00007 | DTFsspwr, DTFsspwr.out |
| **BWR Fuel** | | | |
| Oil (moderator) | 0.52850 | 0.00024 | DTFobwr1, DTFobwr1.out |
| Void (moderator) | 0.16886 | 0.00010 | DTF-bwr0, DTF-bwr0.out |
| Steel (reflector) [a] | 0.11067 | 0.00005 | DTFssbwr, DTFssbwr.out |

[a] The inside of the assembly is dry.

In summary, the calculations for PWR and BWR fuel in the DTF staging racks show that for normal operations that the design is criticality safe. Either spacing between the tubes or line arrangement (straight versus staggered) in the array is acceptable. Further, no fixed neutron poison is required in the cell basket. Also, most of these evaluations were performed under fully flooded moderator conditions for conservatism.

## 6.2    REMEDIATION POOL

The PWR and BWR assembly pitches inside the staging racks as well as the distances between the staging racks were varied from a nominal to a close spacing scenario to evaluate the impact on $k_{eff}$. Table 6.2-1 presents the $k_{eff}$ values as a function of spacing and neutron poison loading in a fully flooded remediation pool. The nominal and close spacing inside the staging racks and between the

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staging racks are defined in Section 5.2.2. The results from Table 6.2-1 indicate that no neutron poison is required for PWR or BWR fuel for a nominal arrangement. For staging racks more closely situated (i.e., the close spacing scenario), no neutron poison is required for BWR fuel but neutron poison should be present for PWR fuel for $k_{eff}$ to be below USL.

Table 6.2-1 PWR and BWR Fuel in Various Remediation Pool Configurations

| DTF Staging Rack Configuration | $k_{eff}$ | St. Dev. | MCNP files |
|---|---|---|---|
| **PWR Fuel** | | | |
| Nominal spacing neutron poison present | 0.86578 | 0.00029 | RB-pwr1, RB-pwr1.out |
| Nominal spacing no neutron poison present | 0.93087 | 0.00027 | RB-pwr2, RB-pwr2.out |
| Close spacing neutron poison present [a] | 0.90811 | 0.00028 | RBpw2aB, RBpw2aB.out |
| Close spacing neutron poison present [b] | 0.91726 | 0.00029 | RBpw2aB1, RBpw2aB1.out |
| Close spacing no neutron poison present | 0.99742 | 0.00029 | RBpwr2a, RBpwr2a.out |
| **BWR Fuel** | | | |
| Nominal spacing neutron poison present | 0.61817 | 0.00027 | RB-bwr1, RB-bwr1.out |
| Nominal spacing no neutron poison present | 0.68446 | 0.00025 | RB-bwr2, RB-bwr2.out |
| Close spacing neutron poison present [a] | 0.80855 | 0.00030 | RB-bw2aB, RB-bw2aB.out |
| Close spacing neutron poison present [b] | 0.82919 | 0.00027 | RBbw2aB1, RBbw2aB1.out |
| Close spacing no neutron poison present | 0.93280 | 0.00026 | RB-bwr2a, RB-bwr2a.out |

[a] Boral loading is 0.02 g $^{10}B/cm^2$.
[b] Boral panel at half width.


## 6.3    CATEGORY 1 AND 2 EVENT SEQUENCE EVALUATIONS

Table 6.3-1 describes the Category 1 event sequences and the applicable criticality safety evaluation performed for each event. Table 6.3-2 provides the criticality evaluation for the Category 2 event sequences.  The supporting calculations for the criticality events and event sequences are provided in the subsections.

Table 6.3-1  Criticality Safety Evaluation for Category 1 Event Sequences

| Event No. | Event Description [a] | Annual Event Frequency | Criticality Safety Evaluation |
|---|---|---|---|
| GET-03D | Drop of a CSNF assembly | 0.50 drops/y | The fuel assemblies are transferred one at a time and a single flooded fuel assembly has a $k_{eff}$ of less than 0.9 (see Section 6.3.1).  Therefore, criticality safety is not an issue for this event. In addition, a potential reconfiguration of a fuel assembly (inside the fuel basket dimensions) will not pose a criticality concern (see Section 6.3.1). |
| GET-03B | Collision involving a CSNF assembly | 0.50 collisions/y | See criticality safety evaluation for event number GET-03D. |

[a] BSC 2005 [DIRS 171429], Section 7

Table 6.3-2  Criticality Safety Evaluation for Category 2 Event Sequences

| Event No. | Event Description [a] | Expected Occurrences [b] | Criticality Safety Evaluation |
|---|---|---|---|
| GET-01A | Drop of a transportation or transfer cask without impact limiters | 5.7E-01 | The transportation casks are unopened and dry on the inside. Section 6.3.2 shows that a dry on the inside cask does not pose a criticality concern even if the fuel assemblies were rearranged. In the event the drop would cause the transportation cask to breach and rearrange the fuel, the moderator height must be controlled (see Section 6.3.2) to remain below USL. |
| GET-02B | Drop of inner lid of a transportation or transfer cask, MSC, or WP into a transportation cask, MSC, or WP | 5.7E-01 | See criticality safety evaluation for event number GET-01A for the transportation cask and MSC (Assumption 3.4). The WP design provides criticality safety for this event per Assumption 3.3. |
| GET-03E | Drop of a CSNF assembly during transfer combined with HVAC failure | 9.7E-02 | See criticality safety evaluation for event number GET-03D (Table 6.3-1). |
| GET-03C | Collision involving a CSNF assembly during transfer combined with HVAC failure | 9.7E-02 | See criticality safety evaluation for event number GET-03D (Table 6.3-1). |
| GET-04B | Drop or collision of handling equipment onto a CSNF assembly | 9.7E-02 | See criticality safety evaluation for event number GET-03D (Table 6.3-1). |
| GET-05B | Drop of a canister during transfer by crane | 5.7E-01 | Section 6.3 of BSC 2005 [DIRS 173284] demonstrates that a rearrangement of fuel for the DOE canisters does not pose a criticality concern. In addition, Section 5.2.3.2 of BSC 2004 [DIRS 170213] shows that losing the skirt, or impact limiter, of the canister due to a drop does not increase the reactivity. |
| GET-06B | Drop of handling equipment onto a canister | 5.7E-01 | See criticality safety evaluation for event number GET-05B |
| GET-07B | Drop of an unsealed WP | 8.6E-02 | The WP design provides criticality safety for this event per Assumption 3.3 (prevents moderator from intruding). Note, however, that moderator cannot intrude into an open/unsealed WP for bounding 5.0 wt% fresh fuel scenarios without exceeding the USL (BSC 2004 [DIRS 172553], p. 30). |
| GET-09C | Drop of a WP with a known closure defect | 2.6E-02 | See criticality safety evaluation for event number GET-07B |
| GET-10C | Drop of a CSNF assembly during dry remediation activities | 4.9E-01 | While $k_{eff}$ will increase if assemblies were reconfigured due to the drop, this event will still not pose a criticality concern as demonstrated by fuel reconfiguration calculations in Section 6.3.1 and Table 6.3-5 (dry activities/scenarios). |
| GET-10B | Collision involving a CSNF assembly during dry remediation activities | 4.9E-01 | See criticality safety evaluation for event number GET-10C. |
| GET-11B | Drop of a canister from a crane during WP remediation or dry remediation activities | 5.7E-02 | See criticality safety evaluation for event number GET-05B |
| GET-12B | Drop of CSNF assembly transfer/handling equipment onto CSNF assemblies in the DTF remediation pool | 4.9E-03 | See criticality safety evaluation for event number GET-03D (Table 6.3-1). |

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Table 6.3-2 (cont.) Criticality Safety Evaluation for Category 2 Event Sequences

| Event No. | Event Description [a] | Expected Occurrences [b] | Criticality Safety Evaluation |
|---|---|---|---|
| GET-13A | Drop of a loaded transportation cask or MSC in the DTF wet remediation area | 1.1E-01 | Regulatory compliance with 10 CFR 50 [DIRS 165855], 71 [DIRS 171308] and 72 [DIRS 173336] provides assurance of criticality safety (MSC per Assumption 3.4). However, drops causing severe fuel rearrangement in open casks should have moderator control (see Section 6.3.4). |
| GET-15C | Drop of an empty or full canister for damaged CSNF assemblies (empty or full) onto or against a cask or basket in the DTF remediation pool | 4.9E-02 | Damaged fuel impacts radiological releases for confinement analysis.  The criticality evaluations already include gap flooding to cover this condition. |
| GET-15B | Collision of an empty or full canister for damaged CSNF assemblies (empty or full) onto or against a cask or basket in the DTF remediation pool | 4.9E-02 | See criticality safety evaluation for event number GET-15C. |
| GET-16C | Drop of a CSNF assembly in the DTF remediation pool | 4.9E-01 | The drop could cause reconfiguration of the CSNF assembly. Section 6.3.1 evaluates the $k_{eff}$ of a reconfigured, fully flooded, CSNF and it remains safely below 0.9. |
| GET-16B | Collision involving a CSNF assembly in the DTF remediation pool | 4.9E-01 | See criticality safety evaluation for event number GET-16C |
| GET-17B | Drop of a filled SNF basket from the spent fuel transfer machine onto the DTF remediation pool floor | 5.4E-02 | The drop could cause reconfiguration of the CSNF assembly. Section 6.3.3 evaluate the $k_{eff}$ of a reconfigured, fully flooded, CSNF in a basket and it remains below USL (with fixed neutron poison present). |
| GET-18B | Drop of handling equipment into or against an opened WP filled with CSNF during dry remediation activities | 4.9E-03 | Studies show that a WP for maximum dry fuel reactivity (i.e., 5.0 wt% fresh fuel) has a $k_{eff}$ below 0.5 USL (BSC 2004 [DIRS 172553], p. I-4).  In addition, Section 6.3.2 shows that $k_{eff}$ is insensitive to fuel reconfiguration (caused by drop/crushing) in dry conditions. |
| GET-19B | Drop of handling equipment into an open WP loaded with DOE canisters or a naval canister during dry remediation activities | 3.6E-02 | See criticality safety evaluation for event number GET-05B for the DOE canisters. It is the responsibility of the U.S Department of the Navy to ensure criticality safety for the naval SNF canister. |
| GET-20B | Drop of a severed dual-purpose canister (DPC) lid back onto the DPC | 1.0E-01 | Regulatory compliance with 10 CFR 50 [DIRS 165855], 71 [DIRS 171308] and 72 [DIRS 173336] provides assurance of criticality safety. |

[a] BSC 2005 [DIRS 171429], Section 7
[b] Before permanent closure

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### 6.3.1    Single and Multiple Spent Fuel Assembly Drop

Category 1 and 2 event sequences include potential drops of single fuel assemblies on a floor, empty rack, empty cask or empty waste package as well as collision with handling equipment, building wall, etc.  For this purpose, a single PWR W 17 x 17 OFA (most reactive fuel type) was modeled in MCNP. The fuel assembly was intact and fully flooded. Compression or compaction of the fuel assembly after the drop would result in a less reactive condition as compared to the intact condition, as demonstrated in Section 6.3.2. However, expansion of the fuel assembly after the drop would result in a higher reactive condition, per Section 6.3.2.

Table 6.3-3 lists on the first data row the $k_{eff}$ of a single PWR fuel assembly (un-poisoned) and it can be seen that the reactivity is considerably below the USL (Section 5.1.3). In addition, calculations of single PWR fuel assemblies (un-poisoned) with the pin pitch reconfigured (i.e., expanded) were also performed. A maximum expansion of the pin pitch inside the fuel basket (pin pitch of 1.36 cm versus the nominal pin pitch of 1.2598 cm) produces a $k_{eff}$ below the USL as shown in Table 6.3-3. Consequently, a drop of a single fuel assembly does not pose a criticality safety concern (even with moderator present). An expanded pin pitch (1.45 cm) beyond the fuel basket structure that produces maximum reactivity (see Section 6.3.2) was also modeled.  It can be seen from the table that this case does, however, exceed the USL. This indicates that the amount of moderator present when handling fuel assemblies needs to be controlled. The table further shows multiple (un-poisoned) PWR assemblies stacked together.  It can be seen that it takes two PWR fuel assembles in order to pose a criticality safety concern.

Table 6.3-3 $k_{eff}$ of Single and Multiple PWR W 17 x17 Assemblies

| Enrichment (wt %) | $k_{eff}$ | St. Dev. | MCNP files |
|---|---|---|---|
| **PWR W 17 x17 OFA (1 assembly - regular 1.2598 cm pitch)** | | | |
| 5.0 | 0.89792 | 0.00028 | pwr-asm1, pwr-asm1.out |
| **PWR W 17 x17 OFA (1 assembly - expanded 1.36 cm pitch)** | | | |
| 5.0 | 0.94063 | 0.00027 | pwrBasm1, pwrBasm1.out |
| **PWR W 17 x17 OFA (1 assembly – maximum 1.45 cm expanded pitch)** | | | |
| 5.0 | 0.99157 | 0.00026 | pwrEasm1, pwrEasm1.out |
| **PWR W 17 x17 OFA (2 assemblies with regular 1.2598 cm pitch)** | | | |
| 5.0 | 0.99999 | 0.00028 | pwr-asm2, pwr-asm2.out |
| **PWR W 17 x17 OFA (3 assemblies with regular 1.2598 cm pitch)** | | | |
| 5.0 | 1.06238 | 0.00028 | pwr-asm3, pwr-asm3.out |

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### 6.3.2    Fuel Reconfiguration

In the event of a drop or collision, fuel may be reconfigured into a new geometry, i.e., either a pitch reduction or increase.  In case of a pitch reduction, this can be modeled by decreasing the fuel pin pitch in the MCNP model. This scenario was evaluated utilizing the MCNP PWR and BWR pin cell models (Section 5.1.8), and featuring reflective boundary conditions to simulate an infinite array of fuel pins.  The pin cell model was fully flooded. Also, note that this study was performed to demonstrate the <u>trends</u> of the infinite multiplication factor ($k_{inf}$) (i.e., not an absolute value) from a drop event, which would result in a pin pitch reduction (due to impact).  Note that $k_{inf}$ values are given instead of $k_{eff}$ values since this is an infinite system.

Table 6.3-4 shows $k_{inf}$ versus pin pitch for PWR and BWR fuel modeled as an array of infinite pin cells (Section 5.2.1). The table indicates that in case of reduction in fuel pin pitch, the reactivity will decrease.

Table 6.3-4 $k_{inf}$ of Pin Pitch Reduction of PWR and BWR Fuel

| Pin Pitch (cm) | $k_{inf}$ | St. Dev. | MCNP files |
|---|---|---|---|
| PWR Fuel (W17 x 17 OFA pin cell model, 5.0 wt % enrichment) | | | |
| 1.25984 (regular) | 1.50521 | 0.00018 | w17ofa5, w17ofa5.out |
| 1.20 | 1.48433 | 0.00024 | w17o12, w17o12.out |
| 1.10 | 1.42603 | 0.00020 | w17o11, w17o11.out |
| 1.00 | 1.32650 | 0.00020 | w17o10, w17o10.out |
| 0.9145 (smallest) | 1.18456 | 0.00020 | w17o09, w17o09.out |
| BWR Fuel (GE 7 x7 Std pin cell model, 4.5 wt % enrichment) | | | |
| 1.87452 (regular) | 1.48306 | 0.00017 | bwr7x7, bwr7x7.out |
| 1.80 | 1.46316 | 0.00019 | bwr18, bwr18.out |
| 1.70 | 1.42416 | 0.00019 | bwr17, bwr17.out |
| 1.60 | 1.36543 | 0.00019 | bwr16, bwr16.out |
| 1.50 | 1.27844 | 0.00020 | bwr15, bwr15.out |
| 1.43003 (smallest) | 1.19414 | 0.00020 | bwr14, bwr14.out |

The same scenario (i.e., pin pitch reduction) was also studied for PWR and BWR fuel in a completely dry environment. As before, this was evaluated utilizing the MCNP PWR and BWR pin cell models (Section 5.1.8), and featuring reflective boundary conditions to simulate an infinite array of fuel pins. Table 6.3-5 shows $k_{inf}$ versus pin pitch for PWR and BWR fuel. It can be seen that $k_{inf}$ is virtually insensitive to pin pitch alterations under dry conditions.

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Table 6.3-5 $k_{inf}$ of Pin Pitch Reduction of PWR and BWR Fuel (Dry Conditions)

| Pin Pitch (cm) | $k_{inf}$ | St. Dev. | MCNP files |
|---|---|---|---|
| PWR Fuel (W17 x 17 OFA pin cell model, 5.0 wt % enrichment) | | | |
| 1.4 | 0.77376 | 0.00017 | w17o14D, w17o14D.out |
| 1.3 | 0.77377 | 0.00015 | w17o13D, w17o13D.out |
| 1.25984 (regular) | 0.77368 | 0.00016 | w17ofa5D, w17ofa5D.out |
| 1.20 | 0.77394 | 0.00015 | w17o12D, w17o12D.out |
| 1.10 | 0.77362 | 0.00016 | w17o11D, w17o11D.out |
| 1.00 | 0.77343 | 0.00019 | w17o10D, w17o10D.out |
| 0.9145 (smallest) | 0.77368 | 0.00016 | w17o09D, w17o09D.out |
| BWR Fuel (GE 7 x7 Std pin cell model, 5.0 wt % enrichment) | | | |
| 2.1 | 0.77856 | 0.00016 | bwr21D, bwr21D.out |
| 1.95 | 0.77890 | 0.00015 | bwr195D, bwr195D.out |
| 1.87452 (regular) | 0.77884 | 0.00012 | bwr7x75D, bwr7x75D.out |
| 1.80 | 0.77873 | 0.00017 | bwr18D, bwr18D.out |
| 1.70 | 0.77896 | 0.00016 | bwr17D, bwr17D.out |
| 1.60 | 0.77897 | 0.00016 | bwr16D, bwr16D.out |
| 1.50 | 0.77901 | 0.00023 | bwr15D, bwr15D.out |
| 1.43003 (smallest) | 0.77899 | 0.00017 | bwr14D, bwr14D.out |

In case of a pitch increase, this can be modeled by increasing the fuel pin pitch in the MCNP model. This scenario was evaluated utilizing the MCNP PWR and BWR pin cell models (Section 5.1.8), and featuring reflective boundary conditions to simulate an infinite array of fuel pins.  The pin cell model was fully flooded. Also, note that this study was performed to demonstrate the <u>trends</u> of $k_{inf}$ (i.e., not an absolute value) from a drop event, which would result in a pin pitch increase (due to impact).

Table 6.3-6 shows $k_{inf}$ versus pin pitch for PWR and BWR fuel modeled as an array of infinite pin cells (Section 5.2.1). The table indicates that in case of an increase in fuel pin pitch, the reactivity will increase.  Figure 6.3-1 graphically displays the results presented in Table 6.3-6 and shows that the peak in $k_{inf}$ occurs at a pin pitch of 1.45 cm for PWR fuel and 2.15 cm for BWR fuel. The data and figure can be found in Excel file *pin_pitch.xls*.

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Table 6.3-6 $k_{inf}$ of Pin Pitch Increase for PWR and BWR Fuel (Flooded Conditions)

| Pin Pitch (cm) | $k_{inf}$ | St. Dev. | MCNP files |
|---|---|---|---|
| PWR Fuel (W17 x 17 OFA pin cell model, 5.0 wt % enrichment) | | | |
| 1.20 | 1.48433 | 0.00024 | w17o12, w17o12.out |
| 1.30 | 1.51560 | 0.00025 | w17o13, w17o13.out |
| 1.40 | 1.52855 | 0.00025 | w17o14, w17o14.out |
| 1.45 | 1.53041 | 0.00021 | w17o145, w17o145.out |
| 1.50 | 1.52921 | 0.00021 | w17o15, w17o15.out |
| 1.60 | 1.52066 | 0.00022 | w17o16, w17o16.out |
| 1.70 | 1.50493 | 0.00021 | w17o17, w17o17.out |
| 1.80 | 1.48424 | 0.00020 | w17o18, w17o18.out |
| 1.90 | 1.45839 | 0.00022 | w17o19, w17o19.out |
| BWR Fuel (GE 7 x7 Std pin cell model, 5.0 wt % enrichment) | | | |
| 1.87452 (regular) | 1.50116 | 0.00017 | bwr7x75, bwr7x75.out |
| 1.95 | 1.51473 | 0.00023 | bwr195, bwr195.out |
| 2.1 | 1.52811 | 0.00022 | bwr21, bwr21.out |
| 2.15 | 1.52924 | 0.00022 | bwr215, bwr215.out |
| 2.2 | 1.52851 | 0.00023 | bwr22, bwr22.out |
| 2.3 | 1.52309 | 0.00019 | bwr23, bwr23.out |
| 2.5 | 1.50050 | 0.00022 | bwr25, bwr25.out |
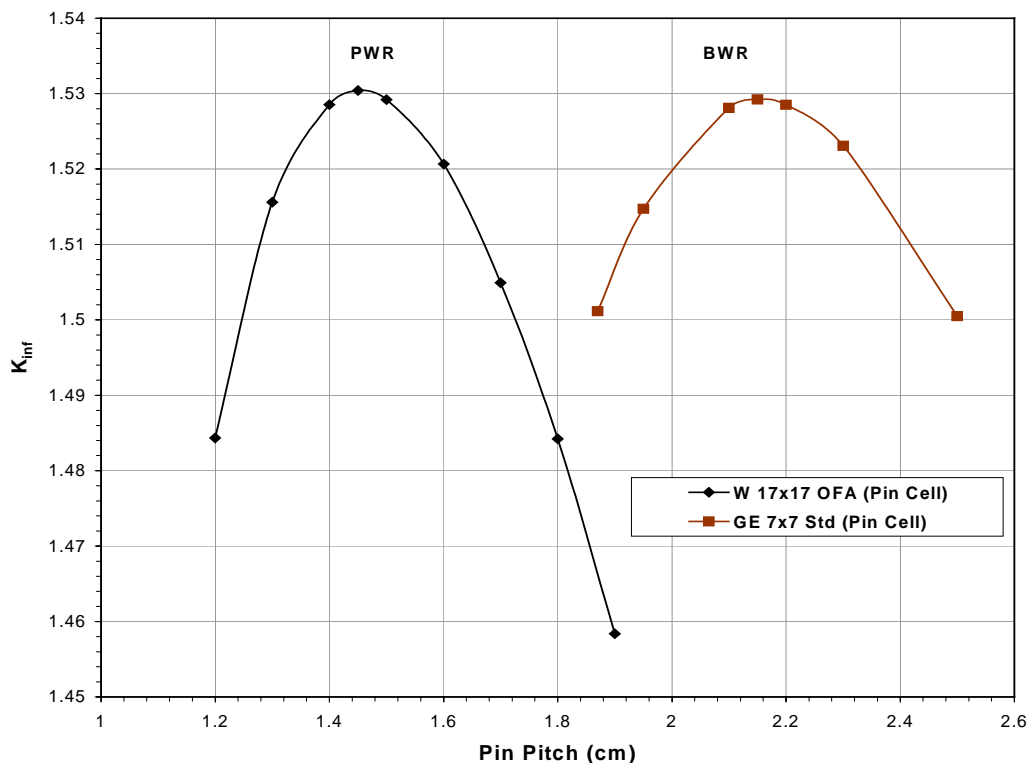


Figure 6.3-1 PWR and BWR Pin Pitch versus $k_{inf}$ for Various Distances

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### 6.3.3 Fuel Reconfiguration in DTF Staging Rack and Remediation Pool

Fuel reconfiguration of PWR and BWR fuel assemblies were evaluated in case of a drop into the staging racks in the DTF or remediation pool. Since the fuel assemblies will be moved one at a time, only one fuel assembly is modeled as reconfigured (entire fuel rod height is at maximum possible pitch inside fuel basket). The DTF staging rack consists of a 9x11 array with 16 in. concrete spacing with both partially and fully flooded tubes and no neutron poison present.  The remediation pool features both the close and regular spacing with 0.02 g $^{10}$B/cm$^2$ Boral loading (both regular and half width Boral panels). Table 6.3-7 shows that moderator control is necessary around the DTF staging racks for a PWR fuel assembly reconfiguration to remain below the USL. The DTF staging racks can be filled with water to a height of approximately 190 cm (50 % of fuel height) when a reconfigured PWR fuel assembly is present in fully loaded DTF staging racks and be safely below the USL  Table 6.3-7 further shows that regular spacing with a neutron poison loading of 0.02 g $^{10}$B/cm$^2$ (regular width) is required in the remediation pool in order to be below the USL in the event of a dropped, reconfigured PWR fuel assembly.  BWR fuel poses no criticality concern in the DTF staging racks or the remediation pool.

Table 6.3-7 $k_{eff}$ of DTF and Remediation Pool Staging Rack with Reconfigured Assembly

| Case | $k_{eff}$ | Standard Deviation | MCNP Files |
|---|---|---|---|
| **Reconfigured Assembly in DTF Staging Rack** | | | |
| PWR fuel –fully flooded, no neutron poison | 0.95058 | 0.00027 | DTFdpwr5, DTFdpwr5.out |
| PWR fuel – 75 % of fuel height flooded, no neutron poison | 0.94931 | 0.00027 | DTFdpwrP, DTFdpwrP.out |
| PWR fuel – 50 % of fuel height flooded, no neutron poison | 0.94557 | 0.00026 | DTFdpwP1, DTFdpwP1.out |
| PWR fuel – 25 % of fuel height flooded, no neutron poison | 0.93051 | 0.00027 | DTFdpwP2, DTFdpwP2.out |
| BWR fuel - fully flooded, no neutron poison | 0.63474 | 0.00027 | DTFdbwr2, DTFdbwr2.out |
| **Reconfigured Assembly in the Remediation Pool** | | | |
| PWR fuel – close spacing, half width Boral panel | 0.97555 | 0.00032 | RBp2aB1d,RBp2aB1d.out |
| PWR fuel – close spacing, 0.02 g $^{10}$B/cm$^2$ | 0.97144 | 0.00028 | RBp2aB2d,RBp2aB2d.out |
| PWR fuel – nominal spacing, half width Boral panel | 0.94508 | 0.00027 | RBp2rB1d,RBp2rB1d.out |
| PWR fuel – nominal spacing, 0.02 g $^{10}$B/cm$^2$ | 0.94389 | 0.00029 | RBp2rB2d,RBp2rB2d.out |
| BWR fuel - close spacing, half width Boral panel | 0.85043 | 0.00028 | RBb2aB1d,RBb2aB1d.out |

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### 6.3.4    Fuel Reconfiguration in HI-STAR Transportation Cask

Fuel reconfiguration was studied for PWR fuel in the HI-STAR transportation cask to ensure criticality safety in the event this would occur due to a drop. Both dry, partially and fully flooded cask inside conditions were evaluated. Since the transportation casks will remain unopened, the dry conditions will represent undamaged transportation cask containment.  In the event a drop punctures the transportation cask containment, fully flooded conditions are conservatively considered.

Table 6.3-8 shows the $k_{eff}$ values for uniformly rearranged PWR fuel (largest possible uniform pin pitch inside the fuel basket) at various water heights in the vertically oriented transportation cask. It can also be seen that fuel rearrangement does not impact $k_{eff}$ significantly during dry conditions ($k_{eff}$ is $0.36610 \pm 0.00010$ for a dry, nominal pitch configuration (BSC 2005 [DIRS 173616], Table 6.1-1)), but an increase in pin pitch during fully flooded conditions causes $k_{eff}$ to exceed the USL under the bounding fresh fuel scenario. The transportation casks can be filled up to about 25 % of the fuel height (about 95 cm above the bottom of the cask) with rearranged fuel (entire fuel rod height) and not be in violation of the USL.

Table 6.3-8 also contains a fully flooded transportation cask with only 50 cm of the bottom portion of the active fuel region reconfigured. Spacers, preventing the fuel from bowing out, are located near the end, as well as approximately 28 cm and 50 cm from the ends, of the fuel assembly (DOE 1987 [DIRS 132333], p. 2A-353). In the event the drop or slap down is not of significant height/force, only a portion of the fuel is more likely to be reconfigured than the entire fuel rod.  It can be seen that with only 50 cm of the fuel reconfigured, $k_{eff}$ remains below the USL for fully flooded conditions.

In the event that hydraulic fluid/oil is present in the facility, due to a leak form the handling crane, a calculation was also performed for a cask containing rearranged fuel (from a drop) partially filled with oil. It can be seen that water is the bounding moderator compared to oil and will not violate the USL.

Table 6.3-8 Comparison of Various Partial Water Flooding Scenarios

| Case [a] | $k_{eff}$ | Standard Deviation | MCNP Files |
|---|---|---|---|
| **Reconfigured PWR fuel in HI-STAR cask** | | | |
| 0 % flooding | 0.36537 | 0.00010 | star15bD, star15bD.out |
| 25 % flooding | 0.93725 | 0.00030 | sta15P25, sta15P25.out |
| 50 % flooding | 0.95444 | 0.00027 | sta15P50, sta15P50.out |
| 75 % flooding | 0.95692 | 0.00026 | sta15P75, sta15P75.out |
| 75 % flooding (oil) [b] | 0.86759 | 0.00028 | sta15O75, sta15O75.out |
| 100 % flooding | 0.95935 | 0.00029 | star15b, star15b.out |
| 100 % flooding (50 cm reconfigured) [c] | 0.93668 | 0.00027 | sta15-50, sta15-50.out |

[a] The percent value listed refers to the portion of the fuel height that is flooded
[b] Oil is used instead of water as a moderator
[c] Only 50 cm of the fuel height is expanded/reconfigured

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## 6.4    CONCLUSIONS AND RECOMMENDATIONS

The processes for the DTF and its remediation area have been evaluated for criticality safety for normal operations, Category 1 and 2 event sequences.  The results presented in this document lead to the following conclusions and recommendations:

- Fixed neutron absorber is required for PWR fuel in the storage racks in the remediation pool to ensure adequate safety margin for both normal operations and Category 1 and 2 event sequences. The minimum spacing between each staging rack is 11 in. in the x-direction and 39 in. between the two rows (y-direction). The spacing between assemblies inside the staging racks is 4.0 in. for PWR fuel (3x3 array) and 3.2 in. for BWR fuel (4x4 array). These spacings require a neutron poison (i.e., Boral) loading of 0.02 g $^{10}$B/cm$^2$ (for PWR fuel). Additional work should be performed if smaller spacing is desired.

- Concrete spacings between the DTF staging tubes of 10 in., 12 in., and 16 in. were evaluated with array sizes of 9x11 and 10x12 (square and triangular pitches). Either configuration is criticality safe under normal operations for both dry and fully flooded conditions.  Further, no neutron poison is needed for PWR or BWR fuel assemblies.

- Category 1 and 2 event sequences potentially occurring in these facilities do not compromise criticality safety. Moderator control is required in the DTF staging rack area in case a drop of a PWR fuel assembly into the DTF staging racks causes fuel reconfiguration. The acceptable water height that can cover the PWR active fuel region in the staging tubes to ensure a $k_{eff}$ below the USL is approximately 190 cm.  Further, a moderator height of 95 cm above the bottom of a vertically oriented transportation cask cannot be exceeded in order to maintain a $k_{eff}$ below the USL.  This is in case a drop of a transportation cask causes a breach that can flood the inside of the cask while also reconfiguring the fuel.

In summary, normal operations in the DTF and its remediation area prove to be criticality safe for CSNF. It should be mentioned that the results for the Monitored Geologic Repository (MGR) Site specific Cask (MSC) calculations are limited to the specific design chosen (see Assumption 3.4). A more current design will be included in the next revision of the criticality calculations for the Aging Facility. During Category 2 conditions, a controlled moderator (i.e., water) height of less than 190 cm above the bottom of the active PWR fuel region in the DTF staging tube is required in order for $k_{eff}$ to not exceed the USL. Further, a maximum moderator height of 95 cm above the bottom of a vertically oriented transportation cask cannot be exceeded in order to maintain a $k_{eff}$ below the USL. It should also be mentioned that although it is not explicitly shown in this calculation, moderator control is also needed in areas with open WPs to ensure criticality safety during Category 2 event sequences.  Attachment III displays the areas requiring moderator control in the DTF.

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**Licensing & Nuclear Safety**                                    **Calculation**

**Title:** Dry Transfer Facility Criticality Safety Calculations
**Document Identifier:** 100-00C-WHS0-00100-000-00C                **Page** 47 **of** 47

## 8.  ATTACHMENTS

This calculation document includes four attachments:

ATTACHMENT I               List of Computer Files

ATTACHMENT II              One Compact Disc

ATTACHMENT III             General Arrangement Drawings of the Dry Transfer Facility and its
                           Remediation Area (secondary references on these drawings are not
                           applicable to this calculation)

ATTACHMENT IV              Sketch of DTF Staging Tube Layouts

**Licensing & Nuclear Safety**                                    **Calculation**

**Title:** Dry Transfer Facility Criticality Safety Calculations
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## ATTACHMENT I
## LISTING OF COMPUTER FILES

All MCNP input and output files documented in this calculation were stored on an electronic medium (compact disc) as Attachment II.  Also, the Microsoft® Excel spreadsheet used to illustrate results are included on the compact disc.

| Date | Time | Size | File |
|------|------|------|------|
| 04/18/2005 | 01:45p | 18,432 | pin_pitch.xls |
| 04/13/2005 | 01:59p | 33,927 | HI-STAR/sta15-50 |
| 04/13/2005 | 01:59p | 604,193 | HI-STAR/sta15-50.out |
| 04/13/2005 | 01:59p | 18,396 | HI-STAR/star15b |
| 04/13/2005 | 01:59p | 521,411 | HI-STAR/star15b.out |
| 04/13/2005 | 01:59p | 34,425 | HI-STAR/PARTIAL/sta15O75 |
| 04/13/2005 | 01:59p | 605,444 | HI-STAR/PARTIAL/sta15O75.out |
| 04/13/2005 | 01:59p | 34,383 | HI-STAR/PARTIAL/sta15P25 |
| 04/13/2005 | 01:59p | 605,667 | HI-STAR/PARTIAL/sta15P25.out |
| 04/13/2005 | 01:59p | 34,384 | HI-STAR/PARTIAL/sta15P50 |
| 04/13/2005 | 01:59p | 605,667 | HI-STAR/PARTIAL/sta15P50.out |
| 04/13/2005 | 01:59p | 34,384 | HI-STAR/PARTIAL/sta15P75 |
| 04/13/2005 | 01:59p | 605,667 | HI-STAR/PARTIAL/sta15P75.out |
| 04/13/2005 | 01:59p | 18,874 | HI-STAR/PARTIAL/star15bD |
| 04/13/2005 | 01:59p | 521,710 | HI-STAR/PARTIAL/star15bD.out |
| 04/13/2005 | 02:00p | 18,496 | DTF-RACK/DTF-pwr |
| 04/13/2005 | 02:00p | 517,094 | DTF-RACK/DTF-pwr.out |
| 04/13/2005 | 02:00p | 18,148 | DTF-RACK/DTF-pwr0 |
| 04/13/2005 | 02:00p | 513,890 | DTF-RACK/DTF-pwr0.out |
| 04/13/2005 | 02:00p | 18,496 | DTF-RACK/DTF-pwr1 |
| 04/13/2005 | 02:00p | 516,856 | DTF-RACK/DTF-pwr1.out |
| 04/18/2005 | 07:09p | 23,684 | DTF-RACK/DTFdpwr5 |
| 04/18/2005 | 07:09p | 537,518 | DTF-RACK/ DTFdpwr5.out |
| 04/13/2005 | 02:00p | 18,295 | DTF-RACK/DTFopwr1 |
| 04/13/2005 | 02:00p | 514,866 | DTF-RACK/DTFopwr1.out |
| 04/13/2005 | 02:00p | 18,153 | DTF-RACK/DTFsspwr |
| 04/13/2005 | 02:00p | 513,897 | DTF-RACK/DTFsspwr.out |
| 05/02/2005 | 10:58a | 40,938 | DTF-RACK/DTFdpwP1 |
| 05/02/2005 | 10:58a | 627,718 | DTF-RACK/DTFdpwP1.out |
| 05/02/2005 | 10:58a | 40,937 | DTF-RACK/DTFdpwP2 |
| 05/02/2005 | 10:58a | 626,234 | DTF-RACK/DTFdpwP2.out |
| 05/02/2005 | 10:59a | 40,938 | DTF-RACK/DTFdpwrP |
| 05/02/2005 | 10:59a | 627,767 | DTF-RACK/DTFdpwrP.out |
| 05/04/2005 | 04:21p | 18,496 | DTF-RACK/10IN/DTF10pwr |
| 05/04/2005 | 04:21p | 514,494 | DTF-RACK/10IN/DTF10pwr.out |
| 05/04/2005 | 04:21p | 20,948 | DTF-RACK/10IN/DTF10tri |
| 05/04/2005 | 04:21p | 526,794 | DTF-RACK/10IN/DTF10tri.out |
| 05/12/2005 | 11:33a | 18,496 | DTF-RACK/10IN/DTF10p10 |

**Licensing & Nuclear Safety** **Calculation**

**Title:** Dry Transfer Facility Criticality Safety Calculations
**Document Identifier:** 100-00C-WHS0-00100-000-00C **Page I-**2 **of I-**5

| Date | Time | Size | File |
|------|------|------|------|
| 05/12/2005 | 11:34a | 515,876 | DTF-RACK/10IN/DTF10p10.out |
| 04/13/2005 | 02:01p | 18,496 | DTF-RACK/12IN/DTF12pwr |
| 04/13/2005 | 02:01p | 515,974 | DTF-RACK/12IN/DTF12pwr.out |
| 05/02/2005 | 11:00a | 17,705 | DTF-RACK/BWR/DTF-bwr |
| 05/02/2005 | 11:00a | 514,282 | DTF-RACK/BWR/DTF-bwr.out |
| 05/02/2005 | 11:00a | 17,625 | DTF-RACK/BWR/DTF-bwr0 |
| 05/02/2005 | 11:00a | 512,698 | DTF-RACK/BWR/DTF-bwr0.out |
| 05/02/2005 | 11:00a | 17,705 | DTF-RACK/BWR/DTF-bwr1 |
| 05/02/2005 | 11:00a | 515,426 | DTF-RACK/BWR/DTF-bwr1.out |
| 05/02/2005 | 11:02a | 17,756 | DTF-RACK/BWR/DTF1-9x9 |
| 05/02/2005 | 11:03a | 515,374 | DTF-RACK/BWR/DTF1-9x9.out |
| 05/02/2005 | 11:00a | 21,525 | DTF-RACK/BWR/DTFdbwr2 |
| 05/02/2005 | 11:00a | 531,749 | DTF-RACK/BWR/DTFdbwr2.out |
| 05/02/2005 | 11:00a | 17,727 | DTF-RACK/BWR/DTFobwr1 |
| 05/02/2005 | 11:00a | 515,039 | DTF-RACK/BWR/DTFobwr1.out |
| 05/02/2005 | 11:00a | 17,631 | DTF-RACK/BWR/DTFssbwr |
| 05/02/2005 | 11:00a | 512,904 | DTF-RACK/BWR/DTFssbwr.out |
| 04/13/2005 | 02:03p | 12,195 | RB-POOL/RB-pwr1 |
| 04/13/2005 | 02:03p | 489,675 | RB-POOL/RB-pwr1.out |
| 04/13/2005 | 02:03p | 12,207 | RB-POOL/RB-pwr2 |
| 04/13/2005 | 02:03p | 489,352 | RB-POOL/RB-pwr2.out |
| 05/02/2005 | 10:54a | 17,313 | RB-POOL/RBp2aB2d |
| 05/02/2005 | 10:54a | 501,075 | RB-POOL/RBp2aB2d.out |
| 04/18/2005 | 12:11p | 17,396 | RB-POOL/RBp2aB1d |
| 04/18/2005 | 12:11p | 472,077 | RB-POOL/RBp2aB1d.out |
| 04/18/2005 | 12:11p | 17,430 | RB-POOL/RBp2rB1d |
| 04/18/2005 | 12:11p | 514,601 | RB-POOL/RBp2rB1d.out |
| 04/18/2005 | 12:11p | 17,347 | RB-POOL/RBp2rB2d |
| 04/18/2005 | 12:11p | 515,657 | RB-POOL/RBp2rB2d.out |
| 04/13/2005 | 02:02p | 12,180 | RB-POOL/RBpw2aB |
| 04/13/2005 | 02:02p | 476,513 | RB-POOL/RBpw2aB.out |
| 04/13/2005 | 02:02p | 11,756 | RB-POOL/RBpw2aB1 |
| 04/13/2005 | 02:02p | 475,139 | RB-POOL/ RBpw2aB1.out |
| 04/13/2005 | 02:03p | 12,191 | RB-POOL/RBpwr2a |
| 04/13/2005 | 02:03p | 475,896 | RB-POOL/RBpwr2a.out |
| 05/02/2005 | 10:50a | 9,680 | RB-POOL/BWR/RB-bw2aB |
| 05/02/2005 | 10:50a | 481,612 | RB-POOL/BWR/RB-bw2aB.out |
| 05/02/2005 | 10:50a | 10,699 | RB-POOL/BWR/RB-bwr1 |
| 05/02/2005 | 10:50a | 483,607 | RB-POOL/BWR/RB-bwr1.out |
| 05/02/2005 | 10:50a | 10,699 | RB-POOL/BWR/RB-bwr2 |
| 05/02/2005 | 10:50a | 469,934 | RB-POOL/BWR/RB-bwr2.out |
| 05/02/2005 | 10:50a | 9,680 | RB-POOL/BWR/RB-bwr2a |
| 05/02/2005 | 10:50a | 481,191 | RB-POOL/BWR/RB-bwr2a.out |
| 05/02/2005 | 10:50a | 14,775 | RB-POOL/BWR/RBb2aB1d |
| 05/02/2005 | 10:50a | 504,687 | RB-POOL/BWR/RBb2aB1d.out |

**Licensing & Nuclear Safety**                                    **Calculation**

**Title:** Dry Transfer Facility Criticality Safety Calculations
**Document Identifier:** 100-00C-WHS0-00100-000-00C                **Page I-**3 **of I-**5

| Date | Time | Size | File |
|------|------|------|------|
| 05/02/2005 | 10:50a | 9,757 | RB-POOL/BWR/RBbw2aB1 |
| 05/02/2005 | 10:50a | 481,612 | RB-POOL/BWR/RBbw2aB1.out |
| 05/02/2005 | 11:06a | 4,999 | ASM/pwr-asm1 |
| 05/02/2005 | 11:06a | 430,292 | ASM/pwr-asm1.out |
| 05/02/2005 | 11:06a | 6,258 | ASM/pwr-asm2 |
| 05/02/2005 | 11:06a | 440,013 | ASM/pwr-asm2.out |
| 05/02/2005 | 11:06a | 6,360 | ASM/pwr-asm3 |
| 05/02/2005 | 11:06a | 440,537 | ASM/pwr-asm3.out |
| 05/02/2005 | 11:06a | 4,995 | ASM/pwrBasm1 |
| 05/02/2005 | 11:06a | 430,292 | ASM/pwrBasm1.out |
| 05/02/2005 | 11:07a | 5,009 | ASM/pwrEasm1 |
| 05/02/2005 | 11:07a | 430,292 | ASM/pwrEasm1.out |
| 02/26/2004 | 10:05a | 2,969 | PinCell/bwr195 |
| 02/26/2004 | 10:05a | 279,566 | PinCell/bwr195.out |
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| 02/26/2004 | 10:05a | 278,290 | PinCell/bwr195D.out |
| 02/26/2004 | 10:05a | 2,965 | PinCell/bwr21 |
| 02/26/2004 | 10:05a | 279,360 | PinCell/bwr21.out |
| 02/26/2004 | 10:05a | 2,969 | PinCell/bwr215 |
| 02/26/2004 | 10:05a | 279,360 | PinCell/bwr215.out |
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| 02/26/2004 | 10:05a | 278,290 | PinCell/bwr21D.out |
| 02/26/2004 | 10:05a | 2,965 | PinCell/bwr22 |
| 02/26/2004 | 10:05a | 279,360 | PinCell/bwr22.out |
| 02/26/2004 | 10:05a | 2,965 | PinCell/bwr23 |
| 02/26/2004 | 10:05a | 279,360 | PinCell/bwr23.out |
| 02/26/2004 | 10:05a | 2,965 | PinCell/bwr25 |
| 02/26/2004 | 10:05a | 279,360 | PinCell/bwr25.out |
| 05/06/2003 | 09:13a | 2,980 | PinCell/bwr7x7 |
| 05/06/2003 | 10:37a | 440,588 | PinCell/bwr7x7.out |
| 07/09/2003 | 02:44p | 2,981 | PinCell/bwr7x75 |
| 07/09/2003 | 12:16p | 440,588 | PinCell/bwr7x75.out |
| 02/26/2004 | 10:05a | 2,962 | PinCell/bwr7x75D |
| 02/26/2004 | 10:05a | 439,502 | PinCell/bwr7x75D.out |
| 07/10/2003 | 10:31a | 2,980 | PinCell/bwr14 |
| 07/11/2003 | 05:33a | 440,588 | PinCell/bwr14.out |
| 02/26/2004 | 10:05a | 2,959 | PinCell/bwr14D |
| 02/26/2004 | 10:05a | 278,496 | PinCell/bwr14D.out |
| 07/10/2003 | 10:26a | 2,964 | PinCell/bwr15 |
| 07/11/2003 | 02:48a | 440,588 | PinCell/bwr15.out |
| 02/26/2004 | 10:05a | 2,944 | PinCell/bwr15D |
| 02/26/2004 | 10:05a | 70,883 | PinCell/bwr15D.out |
| 07/10/2003 | 10:26a | 2,964 | PinCell/bwr16 |
| 07/10/2003 | 04:26p | 440,588 | PinCell/bwr16.out |
| 02/26/2004 | 10:05a | 2,942 | PinCell/bwr16D |

**Licensing & Nuclear Safety**                                        **Calculation**

**Title:** Dry Transfer Facility Criticality Safety Calculations
**Document Identifier:** 100-00C-WHS0-00100-000-00C                **Page I-**4 **of I-**5

| Date | Time | Size | File |
|------|------|------|------|
| 02/26/2004 | 10:05a | 278,496 | PinCell/bwr16D.out |
| 07/10/2003 | 10:25a | 2,964 | PinCell/bwr17 |
| 07/10/2003 | 02:24p | 440,794 | PinCell/bwr17.out |
| 02/26/2004 | 10:05a | 2,948 | PinCell/bwr17D |
| 02/26/2004 | 10:05a | 278,290 | PinCell/bwr17D.out |
| 07/10/2003 | 10:25a | 2,964 | PinCell/bwr18 |
| 07/10/2003 | 12:33p | 440,794 | PinCell/bwr18.out |
| 02/26/2004 | 10:05a | 2,943 | PinCell/bwr18D |
| 02/26/2004 | 10:05a | 278,496 | PinCell/bwr18D.out |
| 07/08/2003 | 09:49a | 3,229 | PinCell/w17o09 |
| 07/08/2003 | 01:30p | 440,667 | PinCell/w17o09.out |
| 03/02/2004 | 12:33p | 3,209 | PinCell/w17o09D |
| 03/02/2004 | 12:33p | 278,307 | PinCell/w17o09D.out |
| 07/08/2003 | 09:50a | 3,209 | PinCell/w17o10 |
| 07/08/2003 | 04:12p | 440,667 | PinCell/w17o10.out |
| 03/02/2004 | 12:33p | 3,191 | PinCell/w17o10D |
| 03/02/2004 | 12:33p | 197,425 | PinCell/w17o10D.out |
| 07/08/2003 | 09:52a | 3,201 | PinCell/w17o11 |
| 07/09/2003 | 02:25a | 440,461 | PinCell/w17o11.out |
| 03/02/2004 | 12:33p | 3,184 | PinCell/w17o11D |
| 03/02/2004 | 12:33p | 278,101 | PinCell/w17o11D.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o12 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o12.out |
| 03/02/2004 | 12:33p | 3,181 | PinCell/w17o12D |
| 03/02/2004 | 12:33p | 278,101 | PinCell/w17o12D.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o13 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o13.out |
| 02/26/2004 | 10:05a | 3,110 | PinCell/w17o13D |
| 02/26/2004 | 10:05a | 278,306 | PinCell/w17o13D.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o14 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o14.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o145 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o145.out |
| 03/02/2004 | 12:33p | 3,111 | PinCell/w17o14D |
| 03/02/2004 | 12:33p | 278,100 | PinCell/w17o14D.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o15 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o15.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o16 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o16.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o17 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o17.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o18 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o18.out |
| 02/26/2004 | 10:06a | 3,128 | PinCell/w17o19 |
| 02/26/2004 | 10:06a | 279,233 | PinCell/w17o19.out |

**Licensing & Nuclear Safety**                                     **Calculation**

**Title:** Dry Transfer Facility Criticality Safety Calculations
**Document Identifier:** 100-00C-WHS0-00100-000-00C            **Page I-5 of I-5**

| Date | Time | Size | File |
|------|------|------|------|
| 05/07/2003 | 08:00a | 3,277 | PinCell/w17ofa |
| 05/07/2003 | 10:10a | 279,280 | PinCell/w17ofa.out |
| 04/19/2003 | 09:31a | 3,275 | PinCell/w17ofa5 |
| 04/19/2003 | 01:03p | 440,461 | PinCell/w17ofa5.out |
| 03/02/2004 | 12:33p | 3,231 | PinCell/w17ofa5D |
| 03/02/2004 | 12:34p | 278,101 | PinCell/w17ofa5D.out |

GROUND FLOOR PLAN A AT EL +0'-0" (UND)

Moderator Control Area

KEY PLAN
FOR REFERENCE ONLY

U.S. DEPARTMENT OF ENERGY

DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
GROUND FLOOR PLAN A

GROUND FLOOR PLAN B AT EL +0'-0" (UNO)

— Moderator Control Area

GROUND FLOOR PLAN C AT EL +0'-0" (UNO)

Moderator Control Area

GROUND FLOOR PLAN D AT EL +0'-0" (UNO)

PLATFORM AT +13'-0"

KEY PLAN
FOR REFERENCE ONLY

Moderator Control Area

**Licensing & Nuclear Safety**                                                      **Calculation**

Title: Dry Transfer Facility Criticality Safety Calculations
Document Identifier: 100-00C-WHS0-00100-000-00C                          Page III-5 of III-26

KEY PLAN
FOR REFERENCE ONLY

— Moderator Control Area

OPERATING FLOOR PLAN A AT EL +32'-0" (UNO)

U.S. DEPARTMENT OF ENERGY
DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
OPERATING FLOOR PLAN A

OPERATING FLOOR PLAN B AT EL +32'-0" (UNO)

*Moderator Control Area*

OPERATING FLOOR PLAN C AT EL +32'-0" (UNO)

Moderator Control Area

KEY PLAN
FOR REFERENCE ONLY

U.S. DEPARTMENT OF ENERGY

DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
OPERATING FLOOR PLAN C

OPERATING FLOOR PLAN D AT EL +32'-0" (UNO)

— Moderator Control Area

UPPER FLOOR PLAN A AT EL +66'-0" (UNO)

GRAPHIC SCALE

0   10  20      40        60 FEET

1" = 20'

KEY PLAN
FOR REFERENCE ONLY

NOTES:

1. FOR DRAWING INDEX, LEGEND & GENERAL NOTES SEE 110-P10-WHS0-00101-000.

2. GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.

THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.

DESIGN INPUTS
SEE DOCUMENT INPUT REFERENCE SYSTEM (DIRS)

U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)
Management and Operation of the Office of Civilian Radioactive Waste Management Program

DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
UPPER FLOOR PLAN A

110-P10-WHS0-00116-000-00A

MATCHLINE 110-P10-WHS0-00116-000

MATCHLINE 110-P10-WHS0-00119-000

UPPER FLOOR PLAN B AT EL +66'-0" (UNO)

KEY PLAN
FOR REFERENCE ONLY

Moderator Control Area

U.S. DEPARTMENT OF ENERGY
DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
UPPER FLOOR PLAN B

**Licensing & Nuclear Safety**                                    **Calculation**

Title: Dry Transfer Facility Criticality Safety Calculations
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UPPER FLOOR PLAN C AT EL +66'-0" (UNO)

MODERATOR CONTROL AREA

UPPER FLOOR PLAN D AT EL +66'-0" (UNO)

KEY PLAN
FOR REFERENCE ONLY

Moderator Control Area

U.S. DEPARTMENT OF ENERGY

DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
UPPER FLOOR PLAN D

EQUIPMENT FLOOR PLAN AT EL -18'-0" (UNO)

EQUIPMENT FLOOR PLAN AT EL -29'-0" (UNO)

DECON/PREP PIT PLAN AT EL -55'-0" (UNO)

KEY PLAN
FOR REFERENCE ONLY

NOTES:

1. FOR DRAWING INDEX, LEGEND & GENERAL NOTES SEE 110-P10-WHS0-00101-000.

2. GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEM OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.

U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)

DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
POOL FLOOR PLANS

SECTION A
2.3.4.5.8.9.12.13.16.17.20.21

SECTION B

Moderator Control Area

SECTION C

Moderator Control Area

**Licensing & Nuclear Safety**                                                                 Calculation
Title: Dry Transfer Facility Criticality Safety Calculations
Document Identifier: 100-00C-WHS0-00100-000-00C

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SECTION D

*Moderator Control Area*

Moderator Control AREA

SECTION F

Moderator Control Area

U.S. DEPARTMENT OF ENERGY
DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
SECTION F

NOTES:

1. FOR DRAWING INDEX, LEGEND & GENERAL NOTES SEE 110-P10-WHS0-00101-000.

2. GENERAL ARRANGEMENTS DO NOT DEFINE THE SAFETY CATEGORIES OF THE STRUCTURE, SYSTEMS, OR COMPONENTS. THEREFORE FLAGS AND BOUNDARIES ARE NOT IDENTIFIED.

SECTION G
2,3,4,5,10,11,14,15,18,19,22,23,24

GRAPHIC SCALE
0  10  20      40        60 FEET
1" = 20'

THIS DRAWING IS PRELIMINARY AND NOT INTENDED FOR CONSTRUCTION, PROCUREMENT OR FABRICATION.

DESIGN INPUTS
SEE DOCUMENT INPUT
REFERENCE SYSTEM (DIRS)

U.S. DEPARTMENT OF ENERGY
Office of Repository Development (ORD)

BECHTEL
SAIC Company LLC  Management and Operation of the Office of Civilian Radioactive Waste Management Program

DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
SECTION G

110-P10-WHS0-00134-000-00B

SCALE 1"=20'
AS NOTED
110p1o0134.dgn

ARCH D - 24"x36"

SECTION

Moderator Control Area

U.S. DEPARTMENT OF ENERGY
DRY TRANSFER FACILITY #1
/REMEDIATION FACILITY
GENERAL ARRANGEMENT
SECTION J

SECTION K

Moderator Control Area

Moderator Control Area

SECTION M

MODERATOR Control AREA

SECTION N

Moderator Control Area

SECTION P

Moderator Control Area